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FAYETTEVILLE STATE UNIVERSITY

ANNUAL REPORT

PROJECT TIMS

(Teaching Integrated Math/Science)

June 11, 1993

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Project Director

(NASA-CR-194288) PROJECT TIMS
(TEACHING INTEGRATED MATH/SCIENCE)
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PROJECT TIMS
(Teaching Integrated Math/Science)

Annual Report

GOAL

The goal of this project is to increase the scientific knowledge and appreciation bases and skills of pre-service and in-service middle school teachers, so as to impact positively on teaching, learning, and student retention.

OBJECTIVES

The established objectives for Project TIMS are as indicated below:

- * To create a pre-service hands-on integrated science/math pilot program.*
- * To provide middle school teachers with direct experiences of scientific investigators, in order to create excitement about aerospace science concepts, make them more aware of careers in science, and teach them about the process of science--its achievements and limitations.*
- * To increase pre-service and in-service knowledge of selected areas of science, with emphasis on experiential learning, and to provide the teachers with ideas and methods for classroom use.*
- * To provide pre-service and in-service teachers with resources and methods for their own continuing education in aerospace related science.*
- * To develop leadership potential of the participants so they can act as agents of change in their schools and/or districts, passing on information and ideas to others and changing teaching methods.*
- * To develop a network of teachers and scientists to provide support, information, and inspiration as the participants work to bring about change in their districts.*
- * To provide more women and minority role models in the sciences, in order to encourage greater participation in science and technology by these under-represented groups.*
- * To develop aerospace related curriculum materials that are socially interactive at the middle school level.*
- * To establish a pre-service hands-on service course that incorporates*

developed curriculum materials.

- * To provide a Summer in-service integrated science and math institute, with a follow-up session in the Fall and in the Spring of 1993-1994.*

PROGRESS

A) The main focus of Project TIMS, to bring together a community of role model university professors and public school teachers to study recommended proactive approaches to teaching and learning science, is a reality. The participating middle school teachers have been chosen and the following university professors have successfully completed year-one scheduled activities: Dr. Akbar Aghajanian, Dr. Wynton Hadley, Dr. Tillman Jackson, and Dr. Ronald Johnston.

B) A working draft of the TIMS curriculum outline has been completed. The outline is currently being reviewed by all participating professors and teachers, and will be finalized by October, 1993.

C) Eight instructional subject-oriented modules have been prepared. The modules are as follows:

- 1. THE UNIVERSE AND STARS —*
- 2. THE SUN AND ITS PLACE IN THE UNIVERSE —*
- 3. OUR SOLAR SYSTEM —*
- 4. ASTRONOMICAL INSTRUMENTS AND SCIENTIFIC MEASUREMENTS —*
- 5. THE MOON AND ECLIPSES —*
- 6. THE EARTH'S ATMOSPHERE: ITS NATURE AND COMPOSITIONS*
- 7. THE EARTH: DIRECTIONS, TIME, AND SEASONS —*
- 8. WINDS AND CIRCULATION*

These subject-oriented modules are designed to maximize flexibility in time and content emphasis for middle school teachers.

D) Three activity modules have also been prepared. The completed activity modules are as follows:

- 1. GOOBOKA (one to five class periods)*
- 2. SPACING OUT THE SYSTEM (one to five class periods)*
- 3. QUANTITATIVE AND QUALITATIVE ANALYSIS (one or two class periods)*

E) The initial field-testing of the modules is currently underway in course, ELEM 635, during first summer session of 1993. Additional activity modules will



be refined in this setting this summer. The complete package of activity modules will consist of 8-12 activities. Some of the activities can absorb 4-6 class periods (45 minutes-one hour) each. All modules will be complete in the month of October, 1993.

F) A draft of the following exercises and informational units have been prepared to accompany the modules:

- 1. Getting Into Space*
- 2. Model Rocketry*
- 3. Balloon Propulsion*
- 4. Simple Hero's Engine*
- 5. Newton Cart*
- 6. Newton's Third Law of Motion*
- 7. Gyroscopic Stability*
- 8. Jupiter's Satellite System*
- 9. Parallax*
- 10. Portable Solar Observatory*

These exercises and units will be completed by October, 1993.

In summary, the project's objections for year-one have been achieved. The project is on schedule for implementation of the workshop for middle school teachers during the summer of 1994.



TIMS PROJECT

Curriculum Outline

(A working draft)

I. GETTING INTO SPACE

- A. How do we get away from the Earth?**
 - 1. Earth's gravitational field
 - a. Velocity of escape
 - b. Orbital velocity
 - 2. Drag of the atmosphere
 - 3. Propulsion
 - 4. Reaction engines
- B. Rocket Design**
 - 1. General Structure
 - a. design of structure
 - b. materials
 - c. aerodynamics heating
 - 2. Multi-stage
 - a. payload
 - b. fuel
 - c. engines
 - 3. Guidance
 - a. inertial
 - b. active
 - 4. Problem of Re-Entry
- C. Model Rockets**
 - 1. Build model
 - 2. Launch model
 - a. determine altitude
 - b. determine average velocity
 - 3. Recovery
- D. Man in Space**
 - 1. The astronaut
 - a. Physical abilities
 - b. mental stability
 - 2. Hazards in space travel
 - a. "weightlessness"
 - b. movement
 - c. isolation
 - d. acceleration
 - e. radiation
 - 3. Biological Aspects
 - a. eating and drinking
 - b. bodily functions
 - c. extended living



II. Exploration of the Solar System

A. Earth as a planet

1. Rotation of Earth on its axis
2. Revolution of Earth about Sun
 - a. Changing sky
 - b. Cause of seasons
 1. Vernal equinox
 2. Summer Solstice
 3. Autumnal Equinox
 4. Winter Solstice
 5. Inclination of axis of rotation
3. Earth as seen from Space

B. The Moon

1. Physical Characteristics
 - a. size
 - b. distance from the Earth
 - c. Shape of orbit
 - d. mass
 - e. surface gravity
 - f. atmosphere
2. Motions
 - a. Revolution
 - b. Phases of Moon
 - c. Rotation
3. Lunar Surface features
 - a. Craters
 - b. mountains
 - c. maria
 - d. minor features
 1. Rilles
 2. Rays
4. Eclipses
 - a. Solar eclipses
 1. partial
 2. total
 3. annular
 - b. Lunar eclipses
 1. partial
 2. total
5. Ocean Tides

C. Other Planets and Members of Solar System

1. Planets and characteristics
 - a. size
 - b. distance from sun
 - c. mass
 - d. surface gravity
 - e. orbit shape
 - f. orbital period
 - g. atmosphere
 - h. rotational period
 - i. escape velocity
 - j. temperature
2. Satellites of the planets
3. Asteriods

4. Comets

III. The Universe

A. The Sun

1. Physical Characteristics

- a. Size
- b. composition
- c. temperature
- d. mass

2. Energy Production

3. Surface and Atmospheric Phenpmena

a. Photoshere

1. Sunspots

- a.cycle
- b. polarity
- c. flares

2. graulations

3. prominences

b. Corona

B. The Stars

1. Characteristics

- a. size
- b. composition
- c. temperature
- d. masses
- e. densities
- f. classes

2. Life Histories

- a. birth
- b. life
- c. death
 - 1. white dwarfs
 - 2. newton stars (pulsars)
 - 3. black holes

C. Galaxies

1. Milky Way

- a.size
- b. shape
- c. mass

2. Other Galaxies

- a. spirals
 - 1.normal
 - 2. barred
- b. optical
- c. irregular

3. Clusters of galaxies

4. Orgin of Universe

- a. Hubblie's Law of Red Shifts
- b. Big Bang

5. Future of Universe

FAYETTEVILLE STATE UNIVERSITY

TEACHING INTEGRATED MATHEMATICS AND SCIENCE FOR MIDDLE GRADES

Our Sun and Its Place in the Universe

CONCEPTS:

The sun is an average-sized, middle-aged star. Its position, size, motions, temperature, and possession of planets do not make it an extraordinary star. But to us on earth, it is the greatest star of all, for our existence depends upon its energy.

The sun rotates west to east on its axis every 25-34 days, and it revolves around our galaxy in approximately 230 million years. Since the sun is not a solid body, all of its parts do not rotate at the same rate of speed. It, however, is rushing through space with a tremendous speed.

The sun has enormous internal and external temperatures resulting from nuclear reactions that principally involve hydrogen and constantly generate energy.

INTRODUCTION

We have always desired to understand the reasons for the various phenomena of nature which are observed in the sky. At a very early date, the idea that the stars and the planets were controlling factors in life became evident, and as a result, man more than likely revered the sun above all other celestial bodies.

While most primitive peoples might have worshipped the sun as a religious fixture, it remained for modern science to show how very dependent our earth and all its life are upon this heavenly body. We now believe that our earth, like each planet in the solar system, is a child of the sun. According to modern theories, the earth and other planets had their origin in material hurled into space from the sun.

The planets revolve around the sun and are held in their orbits by an invisible gravitational attraction that is stronger than bands of

steel. Planets receive light, heat, and all electromagnetic radiations from the sun which is considered the main source of energy within our solar system. Were the sun to "go out" or simply become a cold, dark star, the earth would be plunged into darkness, relieved only by the scant light of the other stars. (The planets and satellites, we must remember, shine by reflected sunlight.) Within a few days, the temperature would be so low that all plant and animal life would be frozen to death. After many days, the bodies of water would be frozen solid; and soon after, the atmosphere itself would freeze, forming first a layer of liquid air upon the surface of the earth, and then a layer of solid air. We are, without question, dependent upon the sun for our food and fuel, for plants cannot grow without the energy of sunlight, and coal and oil are only fossil remains of plants which grew millions of years ago.

Questions

1. What conditions caused man to direct his attention towards a study of the sun?
2. What relationship exists between the planets and our sun? What keeps these celestial bodies from colliding?
3. What type of star is "our sun?" Describe its place in the solar system.
4. What would happen on earth should the sun stop producing energy?

APPEARANCE OF THE SUN

The casual observer will have little interest in the sun and, in general, he takes it for granted. It appears to be a huge ball of light much too bright to be looked at directly. In the summer, we notice that it is high in the sky at noon; in winter it is low in the sky. Few persons realize though, that the sun is always in the southern sky in the Northern Hemisphere, moving east, south, and west; in the Southern Hemisphere it moves east, north, and west, and is, therefore, always in the northern sky.

Compared with other stars, the sun must be classed as an average star. It is neither brilliant nor dim; it is not very hot, nor is it very cool; it is not blue-white, nor is it red. In all respects, the sun must be considered a member of the non-illustrious middle class of stars, specifically a yellow, G +5, main sequence star. It revolves as all stars do in varying periods. It has been estimated that our sun during 5 billion years has revolved around the Milky Way Galaxy twenty-two times at a speed close to 140-170 mi/sec.

Compared to the earth, the sun is a monstrous object. Situated 93,000,000 miles from earth, it still has the earth under its influ-

ence. Due to the elliptic shape of its orbit, the earth gets as close as 91,000,000 miles to the sun. This point in its orbit is called perihelion. In the Northern Hemisphere, this occurs during the winter months. During summer, the earth swings out farther, reaching a maximum distance of about 94,000,000 miles from the sun. When the earth is in this position, it is said to be in aphelion. Because of this change in relative position, the sun's energy is a little more intense on earth in January than it is in July. This tends to produce milder winters in the Northern Hemisphere and cooler winters in the Southern Hemisphere.

When its size is compared to the planets, the sun is a veritable giant. It has a diameter of 864,000 miles which is a hundred times greater than the diameter of our planet, the earth. If the sun were hollowed out, a million earths could be pressed into the sphere and there would be room to spare.

All observations seem to show that the sun is not a rigid body like the earth, but it is an all gaseous material called plasma. By observing the movements of sunspots as they pass across its face and also by the use of the spectroscope, the rate of the sun's rotation can be determined. The astronomer can use the spectroscope to examine the light from one side of the sun as it approaches, and from the other side as it recedes, then compute the difference in terms of line shift and tell almost exactly how fast the sun turns upon its axis.

The sun, as observed from the progression of sunspots, is not turning at all points at the same rate. For example, sunspots near the equator indicate that the sun's sphere at that point rotates once in 24.6 days, at 35° latitude in 26.6 days, and at 80° latitude in 35.3 days. This obviously can mean but one thing—the sun is not a solid body, for parts of a solid sphere would not move at different relative rates of speed.

The extremely high temperatures found in the sun indicate that its mass is not in a liquid state. Estimates of the sun's temperature vary among scientists. Some estimate the surface temperature of the sun at about 10,000°F. Careful calculations on the basis of conditions involved estimate the interior temperature of the sun at about 40,000,000°F. Under these extreme temperature conditions, the sun could not exist in any other state than that of an ionized gas or plasma.

The sun is composed of about 81-90% hydrogen, 8-10% helium, and the remaining percentage is of other elements, more than sixty of which naturally occur on earth. The sun contains more than 99% of the mass of our solar system, and it has about 330,000 times as much mass as the earth. Its density is 1/4 that of the earth's; its gravitational attraction 28 times the earth's; and its volume over

1,000,000 times that of the earth's. Compared to the earth and other planets, the sun is, indeed, an awesome and gigantic celestial body.

Questions

1. How does the sun appear to a casual observer?
2. How would you classify the sun when comparing it to other stars?
3. Describe the aphelion and perihelion positions of the earth's orbit.
4. How would you differentiate between the terms rotation and revolution?
5. How do we know that the sun is not a solid body? Explain.
6. Describe the size of the sun and its distance from the earth.
7. What elements are found in abundance on the sun? Compare its density and gravitational force with that of the earth.

THE PARTS OF THE SUN

Astronomers have assigned names to the different regions of the sun. The luminous surface which is visible in the telescope and upon which the sunspots and other markings are found is called the "photosphere." Above it is the "solar atmosphere" which is composed of luminous, but nearly transparent gases. The solar atmosphere is generally divided into the following regions: a lower atmosphere known as the "reversing layer," a middle one known as the "chromosphere," and an outer layer, that is a gigantic envelope of extremely small density, known as the "corona." The corona is normally invisible.

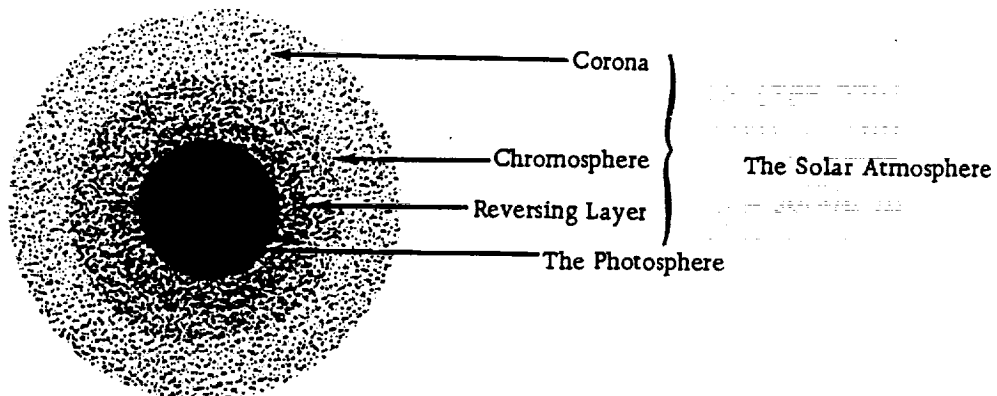


Figure 2-1. The parts of the sun.

Questions

1. What names have been assigned to the different regions of the sun?
2. Differentiate between the solar atmosphere and the photosphere.
3. Why is the corona of the sun normally invisible?

The Photosphere

Through dark glasses, the sun appears as a uniformly bright disc which is that part of the photosphere facing the observer and in which sunlight has its origin. Detailed study of the photosphere reveals that it is not uniformly bright, but it is rather speckled or marked by granulations whose diameters are 150-2,000 miles long. These granulations most likely cover the entire area of the photosphere. They are not fixed on the surface and change constantly in size and in structure. Also appearing on the photosphere from time to time, are sunspots and faculae indicating the varying degrees of increase in local surface brightness of the sun resulting from the turbulent state of the photosphere.

Sunspots are huge areas on the solar disc that appear dark by comparison to the surrounding regions; their diameters are hundreds of thousands of miles. Faculae are areas on the sun's surface that appear brighter in comparison to the surrounding regions; they are thought to be clouds of matter thrown off by the sun that remain above the solar surface for a short period of time.

The granules are believed to be crests of waves that move about constantly in the photosphere. Sunspots resemble tornadoes and seem to begin as internal disturbances just under the sun's surface and at a later stage in their development succeed in creating a break through the photosphere.

Questions

1. Why should the photosphere of the sun be observed through dark glasses?
2. How do sunspots differ from faculae? From granules?
3. Describe the composition of the sun's photosphere.

The Solar Atmosphere

The study of the sun's atmosphere is an achievement of the present century. This was made possible by the invention of the newer instruments used in astronomy, especially the spectroheliograph which is an extension of the spectroscope. This instrument was invented by Professor George E. Hale, although its principle was discovered independently by Hale in America and Deslandres in

France. Professor Hale also perfected an improvement of the spectroheliograph, which he called the spectrohelioscope. This new instrument, instead of taking a photograph, permits visual observation. With it, it is possible to observe visually the instantaneous and amazing changes in sunspots and other solar prominences. An ordinary photograph does not reveal the detailed structure of the sun's upper atmosphere. This is due to the fact that the brilliant glare of light from the photosphere is so intense that all details of the fainter, higher gases of the chromosphere are obliterated by the great blaze of light below.

Before the invention of the spectroheliograph, it was possible to study the solar atmosphere only at the time of a total eclipse of the sun. By focusing a spectroscope on the small rim of sun which remains in view just before the moment of totality, it has been possible to obtain the spectrum of the lower part of the atmosphere, or reversing layer. This spectrum is known as the "flash spectrum," since, unlike the normal continuous spectrum of the sun, it consists of bright lines.

Questions

1. What instruments enable us to study the sun's atmosphere? Who invented these instruments?
2. How would you describe a "flash spectrum?"
3. Before the invention of the spectroheliograph, why was it impossible for man to study the solar atmosphere whenever he desired to do so?

The Reversing Layer: This is the name assigned to the lowest of the three layers in the solar atmosphere. The base of this layer is the surface of the sun; the top extends to about 1,000 miles above the surface. An estimation of the thickness of the reversing layer is obtained from studies of solar eclipses. The time it takes the moon to cross that layer and the known value of the moon's velocity are used in this computation.

The reversing layer is responsible for the many dark lines in the otherwise continuous spectrum of sunlight. The gases in this layer absorb certain wave lengths leaving a resultant spectrum that appears dark in the places usually occupied by these wave lengths.

The wave lengths of the dark lines identify clearly the chemical composition of the reversing layer. Identification is made by comparing these dark line spectra with those spectra produced by chemical elements in the laboratory. All of the elements identified as being present in this layer are found on earth, such as, hydrogen, carbon, nitrogen, aluminum, iron, cobalt, lead, cadmium, and platinum. It is very evident that more elements will eventually be identified in this layer of the sun's atmosphere. During a total

solar eclipse, the background of brighter spectral lines is removed as the moon covers the surface layers at the edge of the sun. For an instant, these dark lines appear as they really are—brilliant—and for a split second the spectrum is reversed.

Questions

1. How would you describe the reversing layer of the sun?
2. How do we know that similar elements found on earth are in the reversing layer? Explain.
3. Why is this layer said to be reversing? How is information gained about this layer of the sun?

The Chromosphere: This is known as the middle layer of the sun's atmosphere. The average thickness of this layer is about 6,000 miles, some areas are 8,000 miles, and others are only 5,000 miles.

The chromosphere owes its name to its bright orange color which is due to hydrogen. Much of the research on the chromosphere can be conducted during daylight. The slit of the spectro-scope is set tangent to the sun's disc so that the sunlight entering the slit is dispersed by the prism and, therefore, greatly weakened. The orange color is in one single wave length and not dispersed. Due to this, light from the chromosphere stands out brightly in comparison with the rest of the light from the sun.

Studies have indicated that the top layer is in constant turbulence, with great masses of gas thrown upward in all directions to tremendous heights. These disturbances may be either prominences or chromospheric flares.

Prominences are those disturbances 15,000 miles or more from the surface of the chromosphere. These spectacular storms often occur in the region of sunspots, lasting from several days to several months. They can best be described as thin sheets of orange-colored flame standing on edge. The dimensions of a prominence are gigantic. Sometimes they reach heights of half a million miles and more; they may exceed the diameter of the sun. The velocity of a prominence is an outstanding feature because of its value and the way it changes. Speeds of 200-300 mi/sec. are common. The change in speed is abrupt, with the new speed a single multiple of the former. Thus, a prominence may be rising at a speed of 80 mi/sec, continue for a period of time at that speed, and suddenly change speeds to 160 mi/sec, and then abruptly start moving at 240 mi/sec.

Intensely bright clouds called "flares" appear from time to time above the chromosphere. These differ from prominences in brilliance, size, and duration. Flares, at their maximum intensity

are easily the brightest spots on the sun, although they are a great deal smaller than prominences. They develop and disappear extremely rapidly, within several hours usually. They are also found in conjunction with active sunspot groups. Scientific interest in chromospheric flares is due to their effect on radio communication, which is greatly disturbed during a "flare period." Normal communications on the earth may be impossible for hours and at times for days.

Questions

1. How would you describe the sun's atmosphere? What two disturbances are frequently observed in this area?
2. Describe the velocity of a prominence. Where do prominences usually occur?
3. How do prominences and flares differ? Why are scientists interested in studying them?
4. How did the term "chromosphere" originate?

The Corona: This is the uppermost layer of the solar atmosphere that is visible to the unaided eye during a total eclipse of the sun. For this reason, the use of an instrument, the coronagraph, is invaluable. The coronagraph is capable of producing an artificial eclipse allowing a study of the corona at any time.

The corona resembles a pearly white halo of intricate design surrounding the body of the sun. It is vastly larger than the two layers beneath it, being roughly a half million miles in thickness. Its shape is closely associated with the eleven-year period of sunspots. It is circular and has few pronounced rays protruding at sunspot maximum. At sunspot minimum, it is elongated and large streamers radiate from it. Within this gaseous envelope, great fiery prominences sometimes shoot up 5,000,000 miles.

Temperatures in the corona can approximate 1,000,000°F; most of this heat is believed to result from motions of the lower layers. Why and how the temperature reaches these heights remain a mystery to us. The density of the corona is so low, one could consider it a vacuum.

Questions

1. When can the corona of the sun be studied by scientists?
2. What is a coronagraph?
3. Describe the corona during sunspot maximum and minimum.
4. What is a vacuum? Why could we consider the corona a vacuum?
5. In size, how does the corona compare with the chromosphere and reversing layer?

SUNSPOTS

The surface of the sun is dotted with dark spots, some of which range from 500 to 200,000 miles in diameter. These sunspots represent relatively cool areas (whose temperature is about 3600-7200°F) as compared with the higher temperatures of the surrounding regions.

It is believed that the sunspots are areas of low temperature that result from the tremendous solar cyclones which increase to a maximum, and then for some undetermined reason, decrease periodically every eleven years. Studies of annual tree rings show that these vary in a similar eleven-year period. When these solar disturbances are at their maximum, magnetic disturbances occur on the earth which interfere seriously with communication or anything electromagnetic in nature.

Since Galileo first discovered them, sunspots have been under constant study by astronomers. Their research into these solar phenomena has been fruitful. It has been revealed that most sunspots consist of two portions that differ greatly in "darkness." The inner portion, called the umbra (Latin for shadow), is the darker of the two. Surrounding the umbra is the semi-dark portion called the penumbra. Although the umbra appears to be dark, its temperature is 3,000°F cooler than the rest of the photosphere. This makes it a "cool" 7,000°F!

Sunspots always appear in pairs and occur in two regions of the sun's surface. These regions are between 5° to 40° north or south of the sun's equator. There are, however, a few exceptions to this rule. About one-half of all sunspots have a life span of four days. Sometimes they last for more than three months. Each sunspot is a center of a magnetic field whose strength varies with the size of the spot. Some sunspots have a north-seeking polarity; others have a south-seeking polarity.

As early as 1843, a definite cycle was proposed for sunspot activity. However, they are found to occur more frequently in recent years. The period of the complete cycle proposed is 22 years; each cycle divided into two eleven-year periods. These half-cycles are similar in their variations in sunspot areas, but they differ in magnetic polarity.

Aside from their interference with radio communication, sunspots also affect the earth's magnetic field, auroras, and even the average temperature of the earth. Some meteorologists claim that the earth's average temperature is lowered by as much as 2°F in the year of sunspot maximum.

Questions

1. In what regions of the sun do "spots" occur? What causes them to occur?
2. How do sunspots affect living conditions on earth?
3. Describe the two regions of a sunspot.
4. How would you describe the complete cycle of sunspots? What is their polarity?

SOURCES OF THE SUN'S ENERGY

The amount of energy from the sun which eventually reaches the earth is enormous. Measured by the pyreliometer, it is found that the earth receives about 160,000 hp. for every human being. The total amount of energy radiated by the sun would be enough to melt a 40 foot shell of ice around it in one minute. It is estimated that the sun sends out energy equivalent to 5,000 billion atomic bombs every second.

Records that have been preserved in the rock layers of the earth indicate that there has been no appreciable and permanent change in the amount of energy that the earth has received during the past billion years. This observation suggests that either there is so much energy that the relative amount lost in a billion years is negligible, or that there are changes taking place within the sun which liberate energy.

Scientists are now certain that the production of energy in the stars (and sun) is the result of nuclear reactions at high temperatures. Stars either burn carbon or hydrogen. In the case of the sun, hydrogen atoms are being fused into helium atoms. The background of this principle was provided by Albert Einstein in his theory of relativity. Before this theory was proposed, it was believed that matter and energy were the constituents of the universe. These separate entities as proposed could be neither created nor destroyed. Einstein, however, stated that energy can be changed into matter. This theory suggests that energy is actually a form of matter. Einstein's concept is expressed by the relation: energy in ergs is equal to mass in grams multiplied by the square of the velocity of light, or $E = m \times C^2$.

The problem of energy production in the sun has been more or less solved by various scientists, among them Hans Bethe. It is now known that each time four hydrogen atoms are converted to one atom of helium in a thermo-nuclear reaction, there is a hydrogen mass loss of about 1%. This mass is converted into energy. At a temperature of 36,000,000°F, this process of converting mass to energy goes on continually. Moreover, the sun will suffer a loss of only 1% of its mass when all the hydrogen has been converted into

helium. The knowledge that the sun still contains abundant amounts of hydrogen leads scientists to the belief that the sun is still relatively young.

Since man has unlocked the secret of the sun's energy production, the information he has obtained may prove invaluable to him in the future. Some investigators believe that nuclear power will be available for mass industrial and commercial purposes. If this proves impracticable, then we will have to depend upon solar power to provide the energy that is necessary for the preservation of life on earth.

Questions

1. Why is it that the energy of the sun does not seem to decrease appreciably?
2. What suggestions have been proposed to account for the sun's enormous and continuous supply of energy?
3. What is the importance of the work of Hans Bethe and Albert Einstein in relation to man's present concept of energy production by the sun?

Activities

Multiple Choice: For each of the following questions, select the number representing the most complete answer and write it in the proper place on the answer sheet.

1. The center of the universe is the: 1. moon, 2. earth, 3. sun, 4. none of these.
2. Primitive man worshipped the: 1. sun, 2. earth, 3. moon, 4. clouds.
3. The sun is considered to be a(n): 1. planet, 2. star, 3. moon, 4. constellation.
4. The distance of the sun from the earth is approximately:
1. 9300, 2. 93,000, 3. 93,000,000, 4. 93,000,000,000 miles.
5. When the earth is closest to the sun, it is said to be in: 1. aphelion, 2. perihelion, 3. peridilion, 4. apherihelion.
6. The diameter of the sun, in miles, is best described by:
1. 86,400, 2. 864,000, 3. 86,400,000, 4. 864,000,000.
7. When the earth is farthest from the sun, it is said to be in:
1. perihelion, 2. apheridilion, 3. peridilion, 4. aphelion.
8. From all observations, the state of the sun is: 1. liquid, 2. solid, 3. gaseous, 4. metallic.

9. The internal temperature of the sun is estimated to be:
1. 40,000°F, 2. 40,000,000°F, 3. 400,000°F,
4. 400,000,000°F.
10. The external temperature of the sun is estimated to be:
1. 1,000°F, 2. 10,000°F, 3. 100,000°F, 4. 1,000,000°F.
11. The part of the sun upon which sunspots and other markings are found is known as the: 1. chromosphere, 2. photosphere,
3. atmosphere, 4. corona.
12. The chromosphere and reversing layer are parts of the sun's:
1. photosphere, 2. corona, 3. atmosphere, 4. all of these.
13. Areas on the surface of the sun that appear brighter in comparison to the surrounding regions are known as: 1. sunspots,
2. flares, 3. faculae, 4. discs.
14. The instrument which enables the study of the solar atmosphere is the: 1. spectroscope, 2. spectroheliograph, 3. telescope,
4. graphoscope.
15. The lowest area of the solar atmosphere is called the: 1. photosphere, 2. corona, 3. reversing layer, 4. lithosphere.
16. The uppermost area of the solar atmosphere is called the:
1. corona, 2. photosphere, 3. chromosphere, 4. reversing layer.
17. Prominences and flares occur in the sun's: 1. atmosphere,
2. photosphere, 3. corona, 4. reversing layer.
18. One of the most outstanding features of the prominence is its:
1. speed, 2. temperature, 3. pressure, 4. color.
19. Sunspots were first discovered by: 1. Einstein, 2. Kepler,
3. Michelson, 4. Galileo.
20. The period of complete sunspot cycles is best described by which of the following number of years? 1. 11, 2. 30, 3. 15,
4. 22.
21. Which of the following best describes the internal portion of a sunspot? 1. penumbra, 2. corona, 3. umbra, 4. chromosphere.
22. In which of the following regions of the sun's surface do "spots" occur? 1. North-South, 2. East-West, 3. North-East,
4. South-East.
23. The half-cycles of sunspots are similar, however, they differ in: 1. number of years, 2. magnetic polarity, 3. magnetic velocity, 4. number of cycles.
24. The sun's energy is known to be produced by: 1. radioaction,
2. nuclear reactions, 3. electronic reactions, 4. reduction reactions.

25. Einstein's concept of matter and energy can best be expressed by: 1. $E = m \times C$, 2. $m = E \times C$, 3. $E = m^2 \times C$, 4. $E = m \times C^2$.
26. The elements that are significant in the sun's production of energy are: 1. hydrogen and helium, 2. carbon and hydrogen, 3. helium and carbon, 4. hydrogen and sulfur.
27. An object has a mass of 20 grams. The energy, in ergs, which this object has when it travels with the speed of light (186,000 mi/sec) is: 1. 691,920, 2. 6,919,200, 3. 691,920,000, 4. 691,920,000,000.
28. An object that travels at the speed of light possesses energy equal to 345,960,000,000 ergs. The mass of this object in grams is: 1. 20, 2. 5, 3. 15, 4. 10.
29. Which is not true of the sun? 1. It is a yellow, average-type star, 2. It rotates and revolves, 3. Its gravitational attraction is 28 times the earth's, 4. It contains less than 75% of the matter in the solar system.
30. The glowing gas layer on the sun that emits light that reaches earth is called the: 1. photosphere, 2. corona, 3. auroral zone, 4. prominence.
31. The sun obtains the principal amount of its energy from: 1. radiation, 2. the combustion of carbon, 3. insolation, 4. none of these.
32. During intense sunspot activity, the sun affects: 1. the earth's magnetic field, 2. short-wave radio communication, 3. cosmic ray intensity, 4. all of these, 5. none of these.
33. Sunspots: 1. appear in pairs, 2. are dark because of their low temperature, 3. provide proof of the sun's rotation, 4. 1 and 2, 5. all of these.
34. The rotation period of the sun is: 1. the same in all latitudes, 2. fastest at the equator, 3. fastest in the high latitudes, 4. zero, because the sun does not rotate.

Matching: Match the numbered items on the right with the lettered items on the left. Place the numbers of your answers in their proper places on the answer sheet.

- | | |
|--|---------------------|
| A. The main source of energy in the solar system | 1. 93,000,000 miles |
| B. Aphelion point in earth's orbit | 2. Corona |
| C. Diameter of the sun | 3. The photosphere |
| D. Region where sunlight has its origin | 4. The sun |

- | | |
|---|-------------------------|
| E. Dark, cool areas on the surface of the sun | 5. Chromospheric flares |
| F. Density so low it is considered to be a vacuum | 6. Telescope |
| G. Very bright areas on the surface of the sun | 7. 91,000,000 miles |
| H. Permits visual observation of the solar atmosphere | 8. Sunspots |
| I. Disturbances that occur about 15,000 miles or more above the surface of the chromosphere | 9. 864,000 miles |
| J. At their maximum intensity, they are the brightest spots on the sun | 10. Spectroheliograph |
| K. The average distance separating the earth and sun | 11. Faculae |
| | 12. 94,000,000 miles |
| | 13. Prominences |

True-False: In the proper places on your answer sheet, place a "T" for the statements that are true and an "F" for the statements that are false.

1. Magnetic storms on the sun do not affect the earth due to the great distance that the earth is from the sun.
2. It has been estimated that the sun has revolved around the Milky Way Galaxy 22 times.
3. The photosphere is visible because it emits a bright-line spectrum.
4. The corona of the sun is the innermost part which is visible only during eclipses.
5. Prominences are evidences of the turbulent state of the sun.
6. Ancient man worshipped the sun as a religious fixture.
7. The energy of the sun is rapidly dissipating.
8. The corona of the sun is denser than its photosphere.
9. The sun is always seen in the southern sky, regardless of the hemisphere from which it is observed.
10. The sun's rotation is considered much slower than the earth's rotation.
11. We have proof of the sun's rotation from sunspot studies.
12. The ancient Greeks are considered to be the founders of astronomy.

TEACHING INTEGRATED MATHEMATICS/SCIENCE FAYETTEVILLE STATE UNIVERSITY FAYETTEVILLE, NC 28301

The Universe and Stars

CONCEPTS:

Cosmogony is concerned with theories of the origin of the universe. Cosmology is a branch of philosophy that is concerned with the origin and structure of the universe. Astronomy is the study of celestial bodies, their sizes, shapes, and structures; it embodies all the characteristics of the universe.

The universe is the sum total of all existing things. It consists of all objects that are members of space, such as stars, planets, satellites, galaxies, and nebulae. The dimensions of the universe have not been determined; however, many scientists believe that there is a limit to this vast heavenly expanse, while others conceive of an infinite universe.

EARLY CONCEPTS OF THE UNIVERSE

Ancient man did little more than gaze into the heavens and amaze himself at its wonders. From his visible observations, he attached many myths and legends to the phenomena which he saw. Early man imagined that he observed figures of animals and men in the star constellations. As time passed, his daily needs led him to investigate the heavens in a more scientific manner and to keep records of the observations which he made. By scientifically using this information, he was able to organize the days, months, and seasons and develop calendars. The Egyptians, for example, developed a calendar based upon a year of 365 days over 6,000 years ago. Finally, when man found that he could use the stars in the heavens to guide him on his journeys over land and water, he invented the science of navigation. Even today, many of the early astronomical observations and relics are still with us, and modern man uses them in furthering his quest for knowledge of the universe and its many wonders.

In this modern age, it will do well for us to remember that the progress which we experience has resulted from the joint efforts of many early civilizations, for the desire of great men of these civilizations was to pursue the quest for truth. Such civilizations as Babylon, Egypt, and Greece are indeed far removed from us, but it was their contributions to the science of astronomy which formed the foundation for the intricate studies that twentieth century man is now endeavoring to undertake. Their conception of the universe was crude, but out of this crudeness man, with the aid of his intellect, has been able to separate truth from fancy.

The Babylonians pictured the universe as a closed chamber with the earth as its floor. Around the earth lay a moat of water, beyond which stood high mountains supporting the dome of the heavens. The Babylonians recognized eclipses and predicted the times that they would occur. They even fixed the length of the year as 365 1/4 days, which represents an error of only eleven minutes more than that which we obtain from our most accurate modern instruments.

The concept of the Hebrews concerning the universe pictured it as a heavenly expanse resting on pillars. This expanse contained windows through which waters that surrounded the firmament could reach the earth. It is certain that the ideas of the Hebrews were based on much less information than we have available to us today.

Among the Greeks, too, the popular idea of the universe included many myths and superstitions. In fact, as with most peoples of that distant time, it is sometimes difficult to determine how one could classify their statements. Perhaps they can be thought of as being based upon "theogony," which is a generalized account of the gods; or they may be thought of as being a part of "cosmogony," which treats of the origin of space and the celestial bodies it contains.

Since classical Greece could claim many brilliant minds, there were naturally many differences of opinion and great confusion between truth and speculation. Some philosophers believed that the earth was a special body in the center of the universe and the stars were fiery bodies nourished by vapor. Some gave the sun the chief place in the heavens, but they placed the stars in the lowest categories.

Although the ancient Greeks had much myth and fancy incorporated in their ideas of the universe, nevertheless, the honor of being the true founders of the science of astronomy must go to them. What was discovered about the heavens by certain illustrious Greeks of the Periclean Age, and of the following period, fills us with astonishment and arouses our most ardent admiration.

These Greek scholars recognized that a solar eclipse is due to the passage of the moon between the earth and sun; and they recog-

nized that the shadow of the earth produces the lunar eclipse. For the older idea of a revolving dome which carried the attached stars with it across the sky, Heraclides substituted the idea that the earth itself rotates and that this alone makes the motion of the stars apparent. Democritus believed that the Milky Way was a vast clumping of stars so far away that it seemed indistinct and misty. It took twenty centuries and the telescope to verify this theory. Eratosthenes measured the inclination of the earth with the plane of its orbit, and set it at 23 degrees and 51 minutes, a figure now known to be but 6 minutes more than the correct value.

Many learned Greeks believed the earth to be round long before the day of Columbus or the voyage of Magellan. They arrived at this conclusion largely as a result of their observations made while journeying down to Egypt to visit the famed library at Alexandria. In making this passage, the travelers noted that the stars, invisible in Greece, arose above the southern horizon and stood far up in the sky by the time they reached their destination in Egypt. These Greeks reasoned that this appearance and seeming movement of the stars could take place only as a result of having traveled over a curved surface. Present data substantiate the fact that the earth is a sphere which is in agreement with the Greek concept. However, most recent data indicate that the earth is really "pear-shaped" with the Southern Pole somewhat flatter than the Northern Pole.

MODERN CONCEPTS OF THE UNIVERSE

Those celestial bodies that compose the universe can be called its "Building Blocks." They are indeed too numerous to be comprehended by the mind of man, however, if he desires to study them more intricately, man must seek to uncover the secrets surrounding the following heavenly bodies and their associated phenomena:

1. The earth upon which man lives and which revolves around the sun;
2. The stars, satellites, and other planets which compose the universe in the same manner that various structures and institutions compose a city; and
3. The different kinds of miscellaneous celestial bodies such as planetoids, comets, meteors, and nebulae.

To the best of our knowledge today, the above celestial objects number eight-nine planets, thirty-one-thirty-two satellites, billions of stars, and countless other distinct classifications of heavenly bodies. As we study the universe with newer and more advanced methods and instruments, its vastness increases tremendously.

Today we can see over 7 billion light years into outer space. With the discovery of quasi-stars, this distance will probably soon

exceed 10 billion light years. Based upon this knowledge, we are observing light that left stars and galaxies billions of years ago.

Questions

1. What caused man to study the celestial objects he observed in a scientific manner?
2. How did the early Greek concept of the universe differ from that of the Babylonians?
3. What were some contributions of early Greece to the science of astronomy?
4. Differentiate between theogony and cosmogony.
5. What is meant by the phrase, "Building Blocks of the Universe?"
6. What is meant by the term universe?

THE STARS

Some of the most interesting things that have been made known to man through the use of the telescope and other astronomical instruments are the data and information regarding the nature of stars. These celestial objects are not the tiny, gentle, shining bodies that they appear to be. Rather, most of them are enormous, blazing infernos that go dashing through space at tremendous rates of speed.

A simple definition of a star is that it is a self-luminous body. Its heat is produced by thermonuclear reactions. Each star radiates light and heat energy into the surrounding space. At their surfaces, they reach temperatures of thousands of degrees; in their interiors, the temperature is much higher. At these temperatures, matter cannot exist either in solid or liquid form. Due to the intense internal heat, the gases constituting the stars are usually much thicker than those on the earth. In short, the stars are suns; our sun is a star.

The stars move about in space although their motions are not noticeable to us with the unaided eye. No change in their relative positions can be detected in a year. Even in a thousand years, the stars will seem to have moved only slightly. Their pattern now is almost exactly the same as it was 1000 years ago. This seeming fixedness is due to the vast distance separating them from us. At these distances it will take many thousands of years for the stellar patterns to undergo noticeable changes; their distance is so great that their relative motions do not become apparent for centuries. This apparent constancy of position accounts for the popular name, "fixed stars."

On a clear, moonless night, the sky seems filled with stars. However, the stars visible to the naked eye are by no means count-

less, as we once believed. By counting them, astronomers have found that the number of stars to be seen by the unaided eye, in both the Northern and Southern Hemispheres, is about 6,000. The number increases rapidly, however, when a telescope is used to scan the sky. Astronomers are certain, therefore, from various considerations, that the number of stars in our galaxy is limited, and their present estimate of the total number is about 100,000,000,000 (one hundred billion).

The Arrangement of Stars

Although the number of stars in the sky seems countless, we have simplified their detection by placing them in two large categories. These categories are known as constellations and galaxies.

Upon our careful observation of the sky, the stars seem to assemble themselves into groups that form patterns. These star groups are called constellations, and even though they are of no scientific significance, they do assist man in naming and locating other stars and celestial objects. The names assigned to the constellations originated with ancient man's idea that the definite groups of stars traced the lines of various objects, such as animals or mythological characters. However, this conception of star patterns is grossly misleading. Stars appear to remain in a fixed position, as previously mentioned, due to their remoteness from earth. They are really whirling through space at terrific rates of speed.

Modern astronomers recognize approximately 88 constellations, many of which are of interest only to the professional observer. Among the number of constellations that are familiar to the layman, although few are well known, are the Big and Little Dippers, Draco the Dragon, Orion the Lion, and the Big and Small Dogs.

The constellation that is easiest for the layman to identify is most likely the Big Dipper. It can easily be seen on any clear night in the Northern Hemisphere. It is important to become familiar with this constellation because it is used as a reference in locating the other constellations, especially the Little Dipper.

In years to come, the whole form of the constellations will be changed. We will then have to assign new names to suit our fancy if we are to continue designating the appearance of these star-groups by animal and mythological names and symbols.

For one to observe the various constellations, the season and latitude are of great importance. Those stars within 45 degrees of the North celestial pole never sink below the horizon and can always be seen. Stars between 45 degrees North and 45 degrees South latitude of the celestial equator can be seen only during certain seasons, and their presence is dependent upon the position from which

they are observed. Those stars within 45 degrees of the South celestial pole cannot be seen by an observer in the Northern Hemisphere.

Polaris, the North Star, is 89-90 degrees high at the earth's North Pole. For this reason it cannot normally be seen below the equator. However, when conditions are perfect, it can be seen from 2 degrees South latitude.

Table 1-1 lists general information concerning some stars and constellations that are important to observers in the Northern Hemisphere. Other data in the table relate to other portions of this chapter.

TABLE 1-1
General Data for Some Stars and Constellations

Constellation	Star	Absolute Magnitude	Apparent Magnitude	Type of Star
	Sun	+4.8	-26	Yellow MS
Canis Major	Sirius	+1.36	-1.6; +8.4	Blue MS
Orion	Betelgeuse	-2.9	+0.92	Red SG
Orion	Rigel	-5.8	+0.34	Blue SG
Scorpius	Antares	-4	+1.2	Red SG
Boötes	Arcturus	-0.1	+0.24	Orange G
Ursa Minor	Polaris			Yellow MS

Most of the great groups of stars and star clusters that are observed seem to belong to closed systems or galaxies. These are large units in the universe, sometimes clustering into small groups or into fantastically large groups. Within the galaxies are star clusters, multiple stars, binary stars, single stars, minute solar systems, nebulae, comets, meteors, and interstellar gas and dust.

There are approximately 10^{12} galactic systems in the universe, each of which contains the same number of stars. Their shapes may be spiral as are 77-80%, elliptical as are 15-20%, or irregular. They are composed of approximately 76% hydrogen, 23% helium, and 1% miscellaneous elements. The average distance between galaxies is 2 million light years, and even at this great distance some of them manage to collide. Usually it is the interstellar material that collides and the stars found within it remain unharmed. These galactic collisions often produce radio waves that can be detected on earth.

Our galaxy, known as the Milky Way Galaxy, is found in a local group of about 20 galaxies. Nearest the Milky Way Galaxy are the irregular-shaped Magellanic Clouds which are 150,000 light years distant and Messier 31 (M 31) or Andromeda with its satellites or companion galaxies about 1 1/2-2 million light years distant. Figure 1-1 shows the shape and appearance of our galaxy; Figure 1-2

is a photograph of two galaxies, one spiral in shape and one termed elliptical mainly because of the absence of spiral arms. By studying these two figures, you should notice definite similarities and differences that exist between galaxies of different shapes.

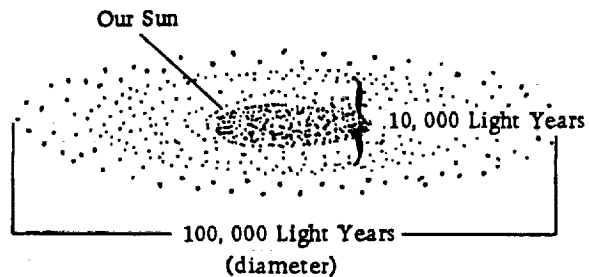


Figure 1-1. Cross-sectional diagram of our galaxy, the Milky Way.

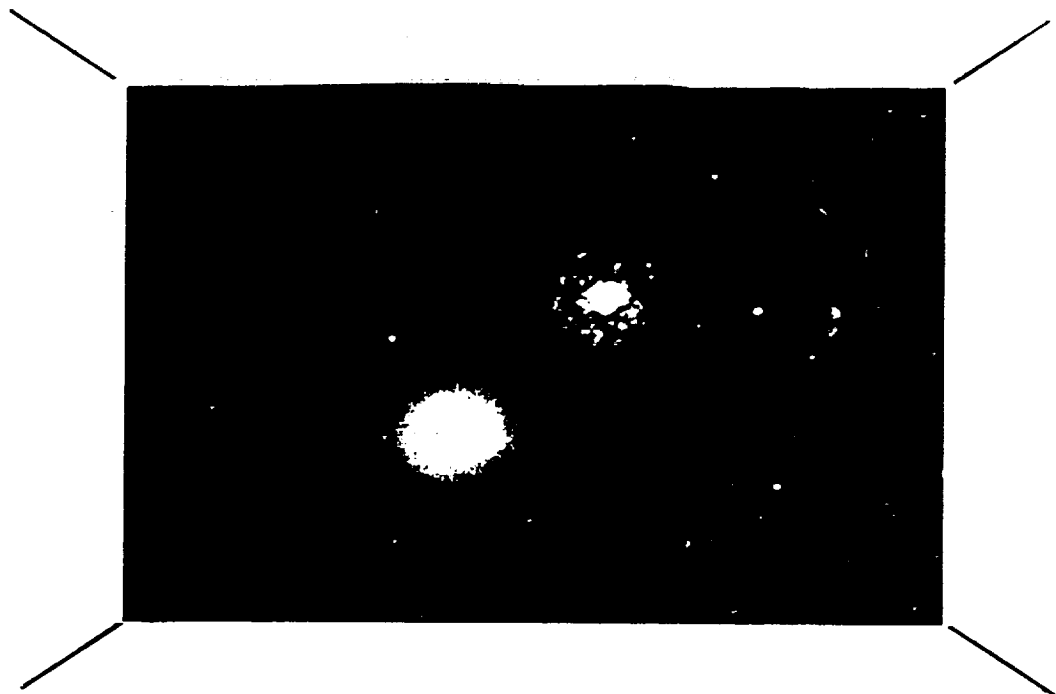


Figure 1-2. A dissimilar pair of galaxies, NGC 4647, 4649 or Messier 60. They are members of the Virgo Cluster. The former is a tightly wound spiral; the latter, an elliptical system.

The stars in the Milky Way Galaxy seem to be arranged in the form of a huge watch. There are 100 billion stars in this galaxy, one of which is our sun. It is located about 30,000 light years from the center of the galaxy.

When we look at the Milky Way, we are looking toward the edge, and for this reason see many more stars than when we look towards either face of the "watch." The brightest direction is toward Sagittarius and the dimmest toward Aurigae. Our galaxy is believed to be spiral in shape, having a thickness of 6,000 to 10,000 light years and a diameter of about 100,000 light years. It is possible that the spin of our galaxy keeps the stars in position.

Above and below the galactic plane of the Milky Way are the globular clusters with many stars but little gas and dust. For this reason, it is believed that these clusters are old in age; the gas and dust having been formed into stellar bodies. Hercules Cluster is an example of a globular cluster. Along the galactic plane are the galactic clusters which are described as young hot stars in a large amount of gas and dust clouds. Pleiades (The Seven Sisters) and Hyades are examples of galactic clusters. The entire system of stars rotates and revolves. About one-half of the material which composes the system is stellar and the other half interstellar. The interstellar material includes gases, separate atoms (mostly hydrogen), and solid particles. In some regions, large dust clouds such as Coal Sack near the Southern Cross are detected. Sometimes large glowing clouds of gas as the Great Nebula in Orion can be seen.

The unorganized gaseous material within a galaxy is known as a nebula. This term also applies to masses of clouds which appear as single stars.

We do not know the true limits of the universe, however, the suggestion of Albert Einstein that his time-space system is closed has attracted a great deal of study. Outer space contains millions of galaxies and by studying them, it may be possible to form better ideas of star origin as well as the size of the universe.

Questions

1. What is meant by the term: Milky Way?
2. Describe three types of galaxies and give an example of each.
3. Define: galaxy, star, nebula, and constellation.
4. Name some constellations visible at your latitude and give the name of the brightest star in each.
5. Can you name a star normally visible only in the Northern Hemisphere? The Southern Hemisphere?

6. What is the closest galaxy to the Milky Way?
7. Distinguish between galactic and globular clusters. Give an example of each.

The Types of Stars

Stars vary in their appearances and in the amount of heat energy they emit. Some stars appear bright as does Sirius, the Dog Star; some like Antares are reddish in color, and a few even appear white as does Vega.

The masses of stars range very little, that is, all stars, with few exceptions, contain roughly the same amount of matter. The diameters of stars, however, vary enormously.

In describing the brightness (magnitude) of a star, several terms are used:

1. The apparent brightness of a star, as seen from earth, is the amount of light that reaches us from the star. This is how bright the star appears to be and this depends upon the distance that the star is from us and its intrinsic brightness.
2. The intrinsic brightness of a star is its true brightness. It is the total amount of light and energy which the star radiates into space.

Since these magnitudes of a star are different, a standard was set up to clarify the erroneous belief that the brightest stars seen with the unaided eye are also intrinsically the brightest. With the aid of the spectroscope, W.S. Adams found a relationship among a star's spectrum, brightness, and distance. This method, however, refers to star brightness in terms of absolute magnitude. Absolute magnitude is simply what the apparent magnitude of a star would be if it were 32.6 light years (10 parsecs) from earth. By using the expression below, any of the three unknown quantities can be determined providing two of them are known.

$$M - m = 5 - 5 \log d$$

Where: M is the star's absolute magnitude; m is the star's apparent magnitude; and d is the star's distance from earth in parsecs.

The apparent magnitude of the sun is -26.72; it is by far the brightest object in our sky. However, if the sun were moved 10 parsecs from us, its magnitude would only be +5. Refer to Table 1-1 and compare the magnitudes of various stars. Note that the smaller the negative number, the brighter the star.

Hertzsprung and Russell (see Figure 1-3) independently plotted the absolute magnitudes of a large number of stars against their

spectral class or color. They found an important relationship between the intrinsic brightness of a star and its surface temperature. When the data were completed with stars grouped according to their magnitude, spectral class, and temperature, most of them fell into an orderly sequence. These main sequence (MS) stars can be as hot as B -3 or as dim and cool as M +10. Astronomers noticed that some of the stars were extremely bright for their calculated surface temperatures. They were over-luminous, usually red in color, large in size, and low in temperature and density. They were named giants (G) and supergiants (SG). Another exception to the main sequence group of stars was a group of extremely hot, very dense, under-luminous stars. Since these stars are thought to be extremely small, they were called dwarfs (D).

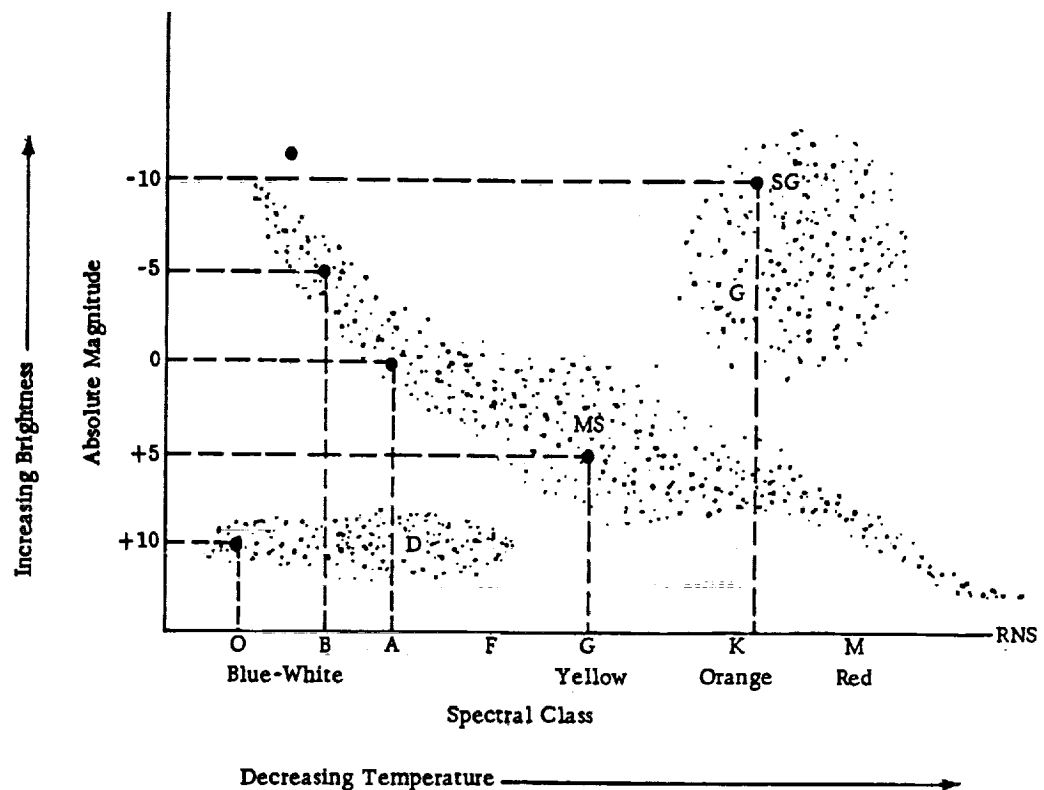


Figure 1-3. Hertzsprung-Russell Diagram

In attempting to account for the behavior of stars, astronomers held to the belief that young stars consist of tremendous volumes of rarefied gases that are barely red hot. Out of this thinking originated the theory that as these gases slowly condensed, the star's

volume becomes smaller and the temperature rises tremendously. The great temperature changes are believed due to the enormous amount of energy that is liberated as the smaller particles unite to form larger, denser particles. When the maximum temperature is reached, the shrinking process continues with a rapid decrease in energy liberation, and the star becomes cooler. Finally, the star becomes red-hot due to the cooling and shrinking processes.

Sometimes small dense stars appear to pass through a second childhood in which they have a last spurt of energy liberation. These stars are known as the white-hot dwarfs, some of which are observed to increase in brightness 100,000 times. Nova Aquilae is now a white star whose size is $1/4$ that of our sun but 70 times as dense. One white dwarf is about the size of our moon, however, its mass is about 40 times that of our sun.

Some white dwarfs become so bright that they can be seen by us in the daytime. This increase in brightness occurs in a cosmic instant, changing from a very faint light to its maximum. The light slowly decreases to its original intensity in about ten years. Such a rapid change can be accounted for only as an explosion. Additional evidence that explosions really take place is offered by the expanding shells of matter that have been observed around several novae*—the name given to these stars. About 150 small, blue-white stars have been observed which are surrounded by shells of luminous material. These planetary nebulae, as they are called, are thought to be old novae. The exact cause of these explosions has not been determined.

We can distinguish between the three basic types of stars referred to by observing the following characteristics of each:

1. The red giants and supergiants are the large, cool stars.
2. The main sequence stars consist of average-size stars similar to our sun (middle-age star) and the small, cool, red stars (old-age stars).
3. The white dwarfs are the very small, bluish-white, very hot stars.

One star that is an exception to all that have been discussed is Rigel, which defies all rules by being a blue supergiant. For this reason, Rigel is considered to be the brightest star that we see in the celestial atmosphere.

* Novae are old stars that flare up or new stars that are born. Supernovae are believed due to hydrogen bankruptcy causing the entire star to be destroyed. Crab Nebula, a radio star, is now 5,000 light years in diameter; it exploded in the year 1054.

Questions

1. Differentiate between the apparent and intrinsic magnitude of stars.
2. Why is a giant star more luminous than a main sequence star of the same spectral classification?
3. Why is a star, reddish to the unaided eye, probably a giant or supergiant?
4. What are novae? Supernovae?
5. How can we distinguish one type of star from another?
6. Discuss the relationship between stellar brightness and stellar temperature.
7. What determines a star's absolute magnitude? What is the absolute magnitude of our sun?
8. Give the characteristics of giant, main sequence, and dwarf stars.
9. Give the characteristics of the stars represented by dots in the Hertzsprung—Russell diagram in Figure 1-3.

Multiple and Variable Stars

Stars that appear as a single beam of light in our sky may actually be twins, triplets, or even quadruplets. Most stars are, in fact, binary or multiple. Polaris, the North Star, is really three stars whose light to us varies in brightness by 10% every 4 days. Its distance from us is 466 light years, therefore, it appears as one star. Castor is really six stars, and Sirius is one blue star with a cooler less massive companion whose revolution period is 50 years. Often, multiple stars are sufficiently far apart to be detected with the telescope. Astronomers believe that as many as one-third or more of all stars in the universe have companions. Sometimes these systems are so far apart, the revolution around their common center of mass requires thousands of years—so many years in fact that, since they have been discovered only a fractional arc of orbit of one about the other has been traveled.

Many times we notice a star whose brightness changes. A star whose brightness is observed to change is referred to as a variable star. It is possible that most stars vary to some degree. Even our sun is believed to vary a little in brightness. Contrasted to these, however, there are many stars whose variation in brightness is one of their prominent characteristics. The study of these characteristics has challenged the astronomer.

There are many reasons why stars can fluctuate in their degree of brightness. The primary cause for this change is believed to be

due to a fluctuation in the surface temperature. However, no completely satisfactory theory with regard to the nature of these changes in the brightness of stars has been proposed. It has been suggested that a collision of two stars is the cause; or that two stars moving close together produce disturbing tides that tear chunks of matter from the surface of these stars; still this phenomenon might occur as a result of a tremendous release of energy within the atoms of the star, resulting in a gigantic explosion. Whatever the true cause for these changes in brightness, one thing is for certain, the flare-up and recession of brightness generally take place within a period of six months. Johann Kepler, in 1604, observed a star that was as bright as the planet Jupiter, and established a record of visibility to the unaided eye for about two years.

Stars that intrinsically change in brightness, as the Cepheid variables, are termed pulsating stars. The Cepheids' periods of pulsation range from less than half a day to several months. Their pulsation periods are related to their absolute magnitudes; every Cepheid with the same period has the same absolute magnitude. This factor enables us to determine their distance from us. If we know the period of pulsation of a Cepheid, its magnitude is also known, and we can use the relationship on page 9 to determine its distance.

Miras are among the largest known stars. Their long periods of variable brightness, low density, and low temperature remain puzzling to scientists.

Eclipsing causes fluctuation in brightness as in some of the instances mentioned. This is probably the simplest explanation for us to assign to the cause of variations in brightness. As one star moves around another, one of the circling companions can cut off the light from the other.

The Doppler shift (spectrum analysis) can also cause a star to vary in its brightness. What appears to us as a change in the brightness of a star could really be a change in the star's motion. This concept will be explained further in the next section.

Questions

1. Discuss reasons why stars vary in brightness.
2. What are the Cepheids? The Miras?
3. Name some multiple or binary stars and the constellation in which they may be located.
4. What is the obvious binary star found in Table 1-1?
5. Cite evidence that stars eclipse.

The Velocity of Stars

It is fairly common knowledge that the "fixed stars" move, and that they do so at rather high rates of speed. Although these stellar speeds are enormous, the stars are so distant that in the course of centuries their movement changes but slightly the shape of the constellations of which they are a part.

Speeds of stars can be determined by analysis of the Fraunhofer lines in their light spectrum. For this analysis, we employ the use of the telescope and spectroscope. If the star from which the light is coming is moving toward us, the light waves are shortened and the lines are said to shift toward the blue end of the spectrum. If the star is moving away from us, the light waves are lengthened and the lines shift toward the red end of the spectrum. The greater the speed of a star, the greater the shift. This principle is known as the Doppler effect, which is named for the Austrian scientist who first recognized the relationship.

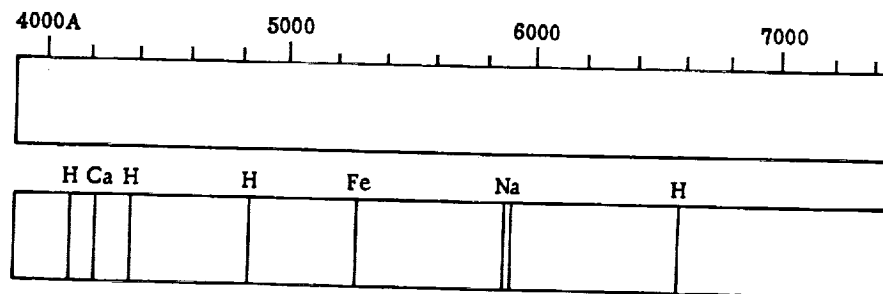


Figure 1-4. A picture of a continuous spectrum, and dark-line (absorption) spectrum.

The measurement of the speed of stars requires great precision, and it is further complicated by the motion of the observer. Since all motion is relative, and not only does the star move, but the observer is also in motion, determining what is moving how fast becomes a problem. The motions involved are numerous; they include the daily rotation of the earth on its axis, slight changes in the direction of the earth's axis, annual revolution around the sun, the movement of the sun and the entire solar system in space, and the movement of the galaxy in the universe. These motions that cause displacements of the stars are called "common motions." They have nothing to do with the real movement of the stars. The "common motions" must be subtracted from the total displacements of the stars to obtain the true motions.

The true speed of a star, which is based on two components, is called "space velocity." One component that is based on the Doppler effect is along the line of sight; it is called the radial velocity. The other component is perpendicular to the line of sight and is called either the "cross motion" or the "tangential velocity" of the star. The transverse velocity is at right angles to the line of sight and tells how fast the star moves in one second. If we consider the diagram in Figure 1-5 while utilizing these terms, we can determine why the formula $V_s^2 = V_t^2 + V_r^2$ enables us to compute the space velocity of a star when the tangential and radial velocities are known.

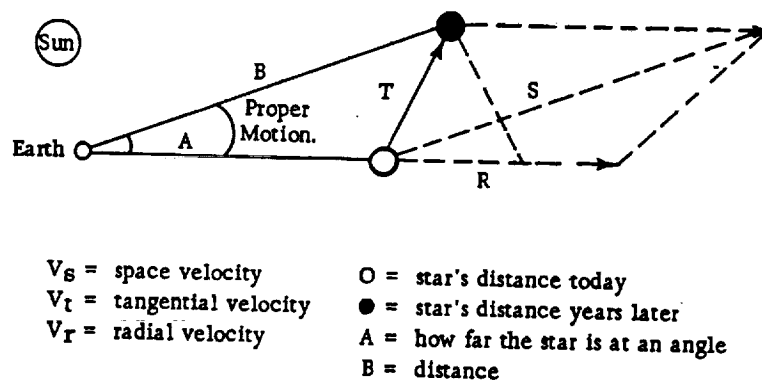


Figure 1-5. Space Velocity

Space velocities usually range from 5-20 mi/sec. The star with the greatest space velocity known to us is Arcturus which travels through space at the rate of 84 mi/sec. However, Barnard's star has the largest proper motion of any star known to us.

The Temperature of Stars

The true brightness of a star depends on its size and temperature. A large cool star may radiate as much light and heat as a small hot star. The temperature of stars varies greatly. On the surface of some stars it may reach only 2500°C, which is 1000° less than the temperature obtained in our best electric furnaces. Other stars may have surface temperatures as high as 30,000°C, while the interiors may reach the 20,000,000°C mark.

Stars must have very high interior temperatures in order to maintain their surface radiation. It has been shown in the Hertzsprung-Russell diagram (Figure 1-3) that surface temperature and color are intimately related. In general, the hottest stars are blue-

white, intermediate temperatures are usually found among the yellow stars, and the coolest stars are red.

Questions

1. What is the average speed of the stars? Traveling at this rate, how many miles would the star travel in one year?
2. What is the Doppler effect?
3. Astronomers believe the universe is expanding. They have based this assumption on the "Red Shift." How could one determine an expanding universe using this shift?
4. List the colors of the spectrum produced by white light in order of their increasing temperature.

The Distances of Stars

One of the most amazing facts about the stars is their great distance from the earth. The nearest to the earth, with the exception of our sun, is most likely Alpha Centauri which is really a double star; its companion, called Proxima, lies below our southern horizon. To the casual observer it would seem that this star could not be more than a few miles away. Yet, its distance is so great, the mile is entirely inadequate as a unit of length. The number of miles mount up so rapidly that our comprehension of the distance is overwhelmed. In order to make the numbers comprehensible in measuring stellar distances, we must use entirely different units. One unit is the light year which is equal to 6,000,000,000,000 miles or simply 6×10^{12} miles. The light year is defined as the distance traveled by a ray of light in a period of one year. Knowing the speed of light is 186,000 mi/sec, it is easy to compute the distance represented by this unit. In terms of light years, Alpha Centauri and Proxima are something like 4.3 light years away from the earth. This means that the light from these stars has been traveling to us for 4.3 years, or that it would take 4.3 years to reach them if we could travel with the speed of light.

Another unit of measurement is the astronomical unit which is equal in length to the average distance from the earth to the sun. This unit is small compared to others and, therefore, it is used primarily to relate distances within our solar system. Thus, the distance to Pluto is 40 astronomical units (A. U.) from the sun. This is derived by dividing Pluto's distance from the sun (3,720,000,000) in miles by 93,000,000 miles.

The definition of the parsec is based on a triangle as shown in Figure 1-6. If angle B is 90° , AB is 1 A. U. long, and angle C is one second of angle in size, then BC will have the length of one parsec.

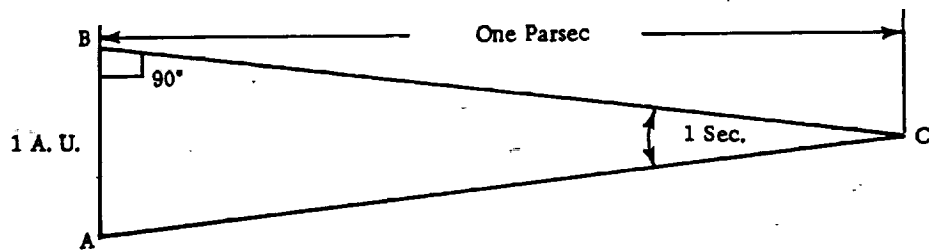


Figure 1-6. A Parsec.

The parsec is an extremely large distance. In terms of miles, one parsec is equal to approximately twenty billion miles. It is 206,265 times as large as one astronomical unit. In terms of the parsec, Alpha Centauri is 1.3 parsecs from the earth. Other stars are hundreds or thousands of parsecs away from us.

The close relationship between the parallax of a star and its distance can be easily determined. One is given by the reciprocal of the other, that is, the number one over the value given. A star having the parallax of 0.5 second is 2 parsecs ($1/0.5 = 2$) distant from the earth.

Distance in parsecs can be converted to light years by using the relationship:

$$\text{One Parsec} = 3.26 \text{ light years}$$

The layman is always astonished by the astronomer's ability to compute enormous star distances. However, the underlying principle is simple, even though the execution of the process is somewhat difficult. The method used is essentially that which is included in surveying; it is known as triangulation. In 1838, a German named Bessel used this method to determine the distances to nearer stars. His method was based upon parallax (or the apparent shift in a star's position) and trigonometry. This method is illustrated in Figure 1-7. The distance AC is determined by measuring three quantities—the length of an arbitrarily chosen line, such as AB, and two angles, A and B. The line AB is called the line of position or base line. Using the line of position and the measured values for the two angles A and B, the distance AC can be determined. Standard formulas from elementary trigonometry are involved in the computational work. Accuracy is obtained when the line of position is comparable in size to the distance that is to be measured. Thus, if AC is estimated to be four miles, the line of position should be several miles long.

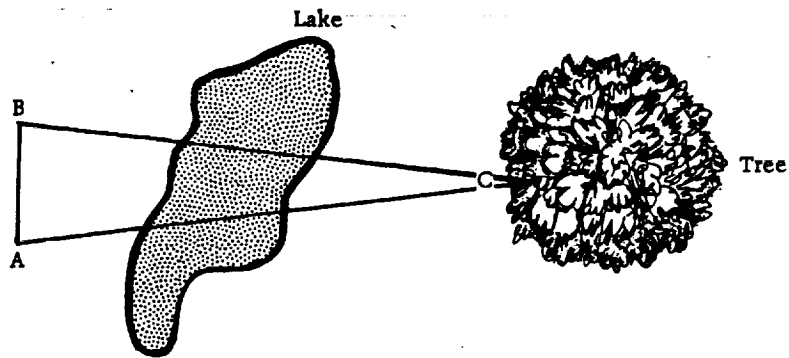


Figure 1-7. Method of triangulation.

The triangulation method can be used to compute the distance to the moon. Telescopes at two observatories, in New York and Chicago, for example, are turned to the moon at the same time. The distance between the two observatories is taken as the line of position. Although this method is satisfactory in this case, the distance to the sun cannot be measured accurately by it because the line of position is too small in comparison to the sun's distance from the earth. However, if one distance in the solar system is known, the others can be calculated from it. One of the asteroids, Eros, periodically approaches close to the earth. At such times, its distance, which is about 16,000,000 miles, can be measured and used in computing the sun's distance from the earth. Once the distance between the earth and sun is known, this value can be used for the line of position (or base line) in measuring remote stellar distances. In this case, the astronomer can point his telescope at a star in January and again in June—twice a year or at 6 month intervals.

In calculating stellar distances by this method, we use the technical term "parallax" to indicate an angle equal to one-half the shift observed in the six-month period between observations. The parallax of a star is, therefore, the amount of shift which would be observed if a star were viewed from earth and then from the sun. The parallax for even the nearest stars is such a tiny angle that the method applies successfully only to those stars that are in close proximity to the earth. During the last twenty years, astronomers have succeeded in measuring the distance of about 2,000 additional stars by the parallax method. This knowledge gives them information upon which reasonable estimates can be made with regard to the distance of more remote stars.

In determining the distance to a particular star "C" by the parallax method, you can study the procedure as it is illustrated in

Figure 1-8. Knowing the size of the angles and the length of the base line, the star's distance can be computed.

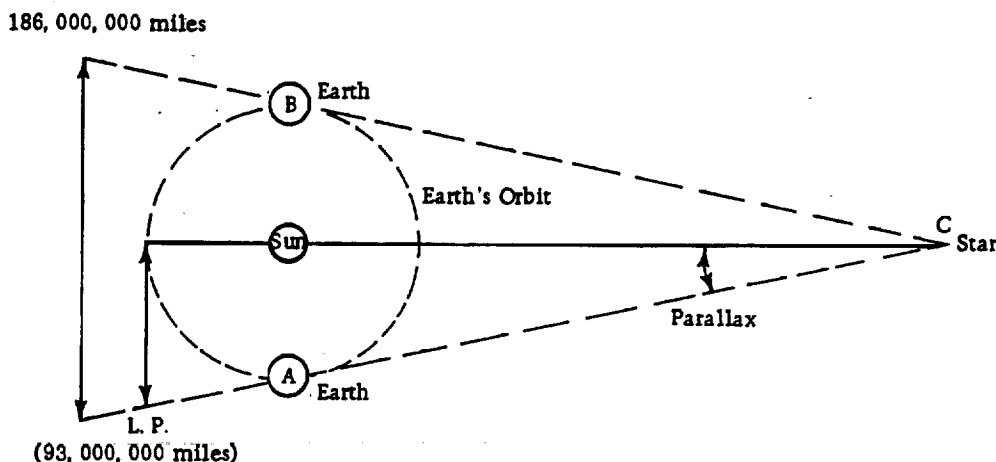


Figure 1-8. Parallax Method where the angles that determine the position of the star when the earth is at point "A" are measured, and six months later, when the earth is at the opposite side of the sun, at point "B", the same angles are measured again.

The radius of the earth's orbit around the sun, and not the diameter, is taken as a line of position or base line. The angle subtended by the star on the radius is called the parallax. The more distant the star, the smaller is its parallax.

The parallax of a star is an extremely small angle. Even Alpha Centauri has a parallax of only 0.756 seconds of an angle. This is a much smaller angle than the diameter of a dime subtended at a distance of one mile. Other stars subtend angles of 0.1 second and even less. The direct method of parallax has been used to determine the distance of more than 6,000 stars. However, the distances to the vast majority of stars cannot be found by this method, for the parallax is much too small to be measured even with the best available instruments. For this reason, the parallactic method can be used to determine star distances within 300 light years of the earth.

To compute the distance of stars and galaxies that are over 300 light years away, we employ several indirect methods of measurement. One such method uses the absolute and apparent magnitudes discussed on page 9. It is here that the Cepheid variable stars play important roles. If they are seen in remote galaxies, for example, their apparent and absolute magnitudes are determined by measur-

ing their periods of pulsation. This gives us the absolute magnitude (M) and the apparent magnitude (m) in the formula $M - m = 5 - 5 \log d$, and leaves only the computation for the star's distance (d) to be made.

Questions

1. Why is it incorrect to measure the distance of a star by triangulation?
2. In measuring stellar distances, how would you differentiate between the method of parallax and the method of triangulation?
3. How do the units for measuring stellar distances differ?
4. Define: parallax, light year, parsec, and astronomical unit.
5. Excluding the use of the radio telescope, describe one way that could be used to compute the distance to:
 - a. A cluster of galaxies
 - b. Proxima
 - c. Sirius
 - d. Andromeda galaxy
 - e. Polaris

Activities

Multiple Choice: For each of the following questions, select the number representing the most complete answer and write it in the proper place on the answer sheet.

1. In terms of light years, how far is the observable universe?
 1. one million,
 2. one billion,
 3. 2 billion,
 4. over 7 billion.
2. A light year is:
 1. a unit of distance,
 2. about 6 trillion miles,
 3. the distance light can travel in one year,
 4. all of these.
3. The most abundant element in the universe is:
 1. hydrogen,
 2. nitrogen,
 3. oxygen,
 4. carbon.
4. The Cepheids:
 1. are variable stars,
 2. change in intrinsic brightness periodically,
 3. 1 and 2,
 4. none of these.
5. The "Red Shift:"
 1. is based upon the Doppler effect,
 2. indicates that spectral lines from distant galaxies are shifting toward the red end of the spectrum,
 3. indicates that the universe is expanding,
 4. all of these.
6. One of the first calendars devised is credited to the:
 1. Syrians,
 2. Samoans,
 3. Egyptians,
 4. Bohemians.

7. When man first observed the heavens, he looked upon celestial phenomena: 1. philosophically, 2. scientifically, 3. dogmatically, 4. superstitiously.
8. Polaris is: 1. really three stars, 2. in the Big Dipper, 3. visible all over the earth, 4. all of these.
9. Which one of the following civilizations pictured the universe as a closed chamber and the earth as its floor? 1. Hebrews, 2. Greeks, 3. Egyptians, 4. Babylonians.
10. In #9, which one of these civilizations first recognized the true cause of eclipses?
11. Galaxies are: 1. spiral, elliptical, or irregular in shape, 2. stationary, 3. 1 and 2, 4. none of these.
12. If an object A were fired from the earth to the sun with the velocity of light, the time which it would take this object to arrive at its destination in seconds is: 1. 50.0, 2. 1,000, 3. 500, 4. 1500.
13. A certain star has a parallax of 0.05 seconds. The distance of this star from the earth in parsecs is: 1. 0.05, 2. 20, 3. 2.0, 4. 200, 5. 1.05.
14. If man could travel with the speed of light, the number of years required for him to travel 12 parsecs would be: 1. 6.5, 2. 5.36, 3. 6.35, 4. 3.6, 5. 38.12.
15. Two stars, A and B, are 25 A.U. apart. This means that in terms of millions of miles, the distance which separates the stars is: 1. 1.93, 2. 3,000, 3. 2325, 4. 186.
16. The parallax of a star which is 10 parsecs from the earth is: 1. 10, 2. 2, 3. 0.1, 4. 20, 5. 1.
17. Three stars, A, B, and C, are respectively 25 A.U., 3 parsecs, and 200 light years distance from earth. The combined distance of the three stars from earth in miles is:
1. $7,070,325 \times 10^6$, 2. $1,020,000 \times 10^6$, 3. $23,250 \times 10^6$,
4. $5,868,987 \times 10^6$, 5. 3583.68×10^{30} .
18. Among the early civilizations, major contributions to the study of astronomy were made by the: 1. Syrians, 2. Chinese, 3. Indians, 4. Greeks.
19. The diameter of the Milky Way Galaxy is considered to be 100,000 light years. If this galaxy were a circle, how many parsecs would its circumference be? 1. 368, 2. 693, 3. 9.6×10^4 , 4. 3.68.
20. The constellation in which we find the star Arcturus is:
1. Orion, 2. Boötes, 3. Scorpius, 4. Canis Major, 5. Ursa Minor.

21. The material that is unorganized and which is found in a galaxy is known as a(n): 1. star, 2. nova, 3. nebula, 4. constellation.
22. The apparent magnitude of a star is -26 due to the fact that its distance from the earth is $.0046$ parsec. The calculated absolute magnitude of this star is approximately: 1. $+5$, 2. $-.1$, 3. $+2$, 4. -3 .
23. When a deficiency of hydrogen in a star causes it to explode and destroy itself, the resulting phenomenon is considered to have taken place in a: 1. nova, 2. galaxy, 3. supernova, 4. constellation.
24. The reason for the star Rigel being classified in a category by itself is due to the fact that it is a: 1. giant, 2. dwarf, 3. blue supergiant, 4. red giant.
25. If we observe the light rays from a star and find that the rays are shorter than they were during a previous observation, we can assume that the star is: 1. moving toward us, 2. moving away from us, 3. not moving, 4. none of these.
26. The distance of a star is measured and found to be 20 parsecs. An astronomer desires to know this distance in terms of light years. His calculations should be: 1. 6.1, 2. 25.6, 3. 65.2, 4. 62.5.
27. A certain line is drawn representing a distance of 2 A.U. This line is constructed at right angles to a second line that represents 2 parsecs. The angle represented by a third line constructed and intersecting the second line, in seconds of rotation, is: 1. 1, 2. 2, 3. 3, 4. 4.
28. The absolute magnitude of a star is -5.8 and it is 930,000,000 miles from earth. Its apparent magnitude is: 1. -3.74 , 2. $+374.0$, 3. -37.4 , 4. 473.9 .

Matching: Match the numbered items on the right with the lettered items on the left. Place the numbers of your answers in their proper places on the answer sheet.

- | | |
|---|------------------|
| A. Nearest star to earth | 1. Rigel |
| B. Eclipsing bright star | 2. Polaris |
| C. Double star that is also called Alpha Centauri | 3. Sirius |
| D. Brightest known star | 4. Proxima |
| E. 466 light years away from earth | 5. None of these |
| F. 4.3 light years away from earth | |
-

- G. The density of a red star _____ the density of a blue-white star. 1. is less than
2. is equal to
3. is more than
- H. The surface temperature of a blue star _____ the surface temperature of a red star.
- I. The surface temperature of a B-5 star _____ the surface temperature of a G+5 star.
- J. The size of a K-8 star _____ the size of a 0+10 star.
- K. The absolute magnitude of our sun _____ the absolute magnitude of Sirius.

-
- L. The coolest main sequence star in the list 1. K-8
2. G+5
3. B-5
4. 0+10
- M. A giant or supergiant
- N. Our sun
- O. The dimmest star according to magnitude
- P. A dwarf
- Q. A yellow type star
- R. The hottest main sequence star in the list
- S. A red star

True-False: In the proper places on your answer sheet, place a "T" for the statements that are true and an "F" for the statements that are false.

1. There are billions of stars in the universe.
2. There are millions of stars in our solar system.
3. The sun is the hottest known star.
4. The parallax method of computing star distances is the most useful that is known to man, since most stellar distances can be determined by this method.
5. Magellanic Clouds are the nearest neighbors to our galaxy.
6. Most stars are binary or multiple.
7. Our galaxy is approximately 100,000 miles long and 10,000 miles thick.
8. The stars we see represent the past, not the present.
9. The Milky Way is a system of stationary stars.
10. In order to see a constellation, we must be at a certain latitude on a certain date.

Thought Questions: Record your answer to each of the following questions in its proper place on the answer sheet.

1. Can you ascribe any natural phenomenon to the "Star of Bethlehem?"
2. Even though stars like our sun are more dense than water, how does man know that they are really gaseous or in a plasma state?
3. In the universe, what are the different motions of the earth? Give the approximate speed of each motion.
4. Why does the outer portion of a galaxy move more slowly than the central portion?
5. Write about a constellation. Include in your work: its history, when it is seen, how we can locate it, the important stars that are found in it, and the changes in its shape that have evolved over the centuries.
6. If Sirius were 1000 parsecs from the earth, how bright would it appear to us earthlings?

FAYETTEVILLE STATE UNIVERSITY

TEACHING INTEGRATED MATHEMATICS AND SCIENCE FOR MIDDLE GRADES

Our Solar System

CONCEPTS:

Scientists recognize that out of the innumerable celestial bodies in the universe there are other solar systems that exist which are not a part of "our solar system."

The life-long work of many early investigators has resulted in our modern concepts of the universe. Most of these early investigations present some disagreement with present findings; however, the works of Claudius Ptolemy, Nicholas Copernicus, Tycho Brahe, Johann Kepler, and Galileo Galilei will always be fundamental to an understanding of "our solar system" and its place in the universe.

The planets are large bodies of matter that shine by reflected sunlight. They revolve about the sun in a counterclockwise manner and have orbits that are elliptical in nature. They rotate on their own axes; rotation is usually counterclockwise.

Planets are located in space at tremendous distances from the sun. Scientists believe that the conditions on some planets are conducive to life; however, there are planets too close or remote from the sun to possess conditions suitable for the type of life known to man on the earth.

EARLY IDEAS ABOUT OUR SOLAR SYSTEM

In order for him to account for the orderliness of nature and observed astronomical facts, early man made basic assumptions to describe the nature of the universe. In the third century B.C., Aristarchus proposed a heliocentric or sun-centered hypothesis of the universe. This conception had little influence upon the Greeks, for they assumed the earth to be the central body in space. This original hypothesis of the Greeks is contained in what is now referred to as the Geocentric, earth-centered, or Ptolemaic System.

The latter is named in honor of Claudius Ptolemy who was one of their great astronomical contributors. The Ptolemaic picture of the heavens was accepted by most of the Greek astronomers. In the second century A.D., Ptolemy worked out an ingenious and intricate combination of circular motions from which he could compute the known motions of heavenly bodies. His concepts, recorded in a thirteen-volume treatise called the Almagest, persisted for centuries before it became obvious to investigators that they were inaccurate. However, if one simply uses naked-eye observations, this geocentric system appears to work. A simplified diagram of Ptolemy's system is illustrated in Figure 3-1. To understand this system, one must assume that:

1. The universe is a huge sphere with stars embedded in its surface. This sphere rotates every 24 hours.
2. The five planets not only move with the sphere, but they may also have a secondary motion called an epicycle.
3. The earth is stationary.
4. All motion in nature is circular.

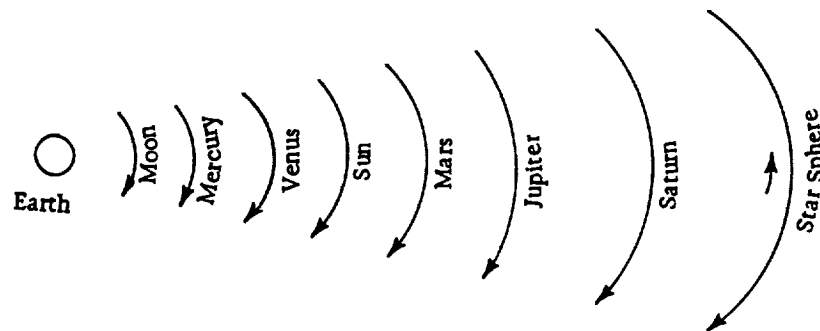


Figure 3-1. Ptolemy's System of the universe.

Due to the rebirth of learning which took place during the Renaissance Period, various scholars began to challenge the Greek way of thinking. Among other things, commerce was beginning to thrive, universities were rising, a national consciousness was emerging, and the spirit of inquiry was rekindled among scholars. The result was a critical attitude manifested in the refusal to accept a concept as true just because it carried the label of authority. When a postulate was set forth, the scholars of the Renaissance demanded to know what observable facts supported it. If no plausible evidence could be produced, the postulate was rejected. When this attitude became pronounced, the dawn of science and of scientific

discovery was on the horizon—an advance which revolutionized man's thinking and brought forth a genuine flood of dependable truth. This new critical method of inquiry is without a doubt the supreme intellectual contribution of the scientific age.

The first modern scientific thinker and the originator of modern astronomy was Nicholas Copernicus. Copernicus had the advantage of the best schools in his country and he studied under skilled teachers of medicine, mathematics, and astronomy. At the age of 27, because of his unusual ability, he was made professor of mathematics at Rome. One of his chief duties in this connection was to expand the teachings of Ptolemy, whose concepts and ideas had dominated man's thinking and persisted all these centuries. In 1502, Copernicus departed from Rome and entered a religious order in his native Poland. Here, he began his study of the stars. He deduced that they and other heavenly bodies must be vast objects at tremendous distances from the earth. It did not seem plausible to him that the stars could be attached to a huge revolving dome or sphere as Ptolemy had taught, and the more he studied, the more he became convinced that fundamental errors permeated the work of Ptolemy. In fact, he found so many errors in the Ptolemaic tables that he came to distrust all the teachings of Ptolemy.

In 1507, Copernicus began preparing his famous book entitled De Revolutionibus Orbium Caelestium which means Concerning the Revolutions of the Heavenly Bodies. His main thesis was that the center of the solar system was the sun and the earth is but one of the planets revolving around the sun. He also advanced the modern concepts that the moon revolves around the earth, accompanying the earth in its revolution around the sun, and that the earth turns on its axis from west to east, thus accounting for day and night as well as the apparent motion of the stars.

For almost thirty years, Copernicus worked on his new theory of the universe with scarcely a day or night passing that he did not add something to it. One would suppose that such an historical concept, which avoided the old Ptolemaic errors and brought order into an understanding of the universe, would have been received with enthusiastic approval. But, it was not. Copernicus had a grasp of great astronomical truths which was far ahead of his time, and he had to suffer because of his advanced ideas. When he died, the world was still unwilling to accept his heliocentric theory. This was evident from the fact that medieval universities continued to teach the Ptolemaic theory of the universe. Without a doubt, many learned professors, to say nothing of the general public, never even heard of the book Copernicus had written.

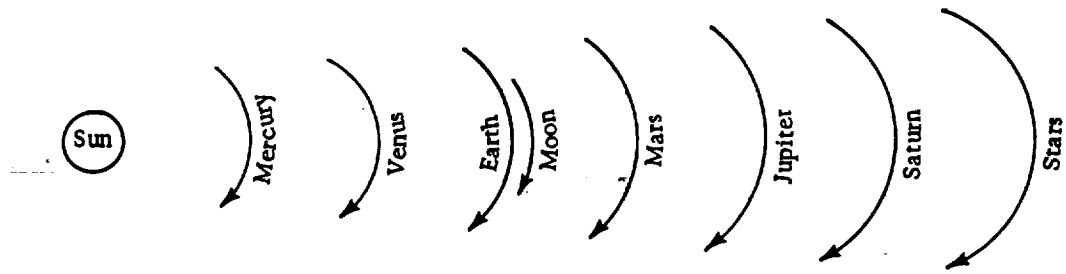


Figure 3-2. The Copernican System of the universe.

The thinking of investigators of that early age should be quite understandable to us who live in this "modern age," for there were several criticisms of the Copernican System which could not be corrected or explained at that time. As examples, no explanation could be offered then to the questions, "Why is it that loose objects do not fly off the earth?" or "Why is it that man does not get dizzy as a result of his movements with the earth?" Inquisitiveness of this nature left enormous gaps for further research and study. In considering the answers to the questions proposed, however, modern man must entertain the fact that during the 16th century, very little was known about the laws of gravitation, and as a result, investigations were necessary to support or refute the teachings of Copernicus.

Nevertheless, Copernicus had followers who were so devoted to him that they constantly sought to prove his heliocentric theory. A simplified diagram illustrating the concepts of this system is shown in Figure 3-2. The essence of this system can be summarized thus:

1. The sun is a static body in the center of the universe.
2. The planets move about the sun in circular orbits, with some of them moving faster than others.
3. The stars are fixed on a moving sphere.

As we well know today, these were the concepts of the solar system that pioneered great works in the field of astronomy. Notably among these were the works of Tycho Brahe, Johann Kepler, and Galileo Galilei.

Questions

1. List the similarities and differences between the Ptolemaic and Copernican Systems of the universe.

2. Was the Ptolemaic System a better scientific theory than the Copernican System?

3. Read about Copernicus and Ptolemy in Chapter 6.

Tycho Brahe (1546-1601) was a strange character with a fiery temper. His interest in astronomy was aroused by an eclipse of the sun coming at the same time predicted in 1560. Although he could see how well the Copernican System explained the motions of the planets, Brahe was not willing to believe that the earth itself was in motion. Often described as a man blessed with exceptional eyesight and patience, Brahe made thousands of measurements of celestial objects and left superlative data for his contemporaries to analyze.

Johann Kepler (1571-1630) tried to reconcile Brahe's observational data with models of the solar system and to organize mathematical relationships. Since he was a student of Brahe, he inherited his teacher's data of celestial observations. Kepler was a German mathematical genius and after years of almost uninterrupted calculations, he published in 1609 a book containing what we now term Kepler's Laws of Planetary Motion. These laws substantiate most of the heliocentric theory; the main exception concerns the type of orbit that Copernicus had visualized. Copernicus was right in placing the sun at the center, but the planets revolve in flattened circles or ellipses, not circles. The laws formulated by Kepler resulted from his manner of thinking and his belief in a definite order and regularity in the universe.

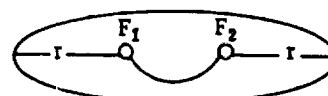
The first law of planetary motion states that each planet revolves around the sun in an elliptical orbit. The second law describes the ellipse and planetary motion with the sun at one focal point. And, the third law illustrates mathematically the relationship between a planet's revolution period and its distance from the sun. To concretely illustrate these principles, we can refer to the analyses and diagrams that follow.

1st Law: "The orbit of each planet is an ellipse with the sun at one of the foci." The other point of focus is space.

- (a) An ellipse is a curve on which any point equals the sum of the two foci. If the two foci are at the same point, the figure is a circle. Refer to Figure 3-3.



Circle



Ellipse

Figure 3-3. The circle and ellipse where F is a focus point and r is a radius vector.

- (b) An ellipse is a curve so drawn that the sum of the distance from the two foci to any point on its circumference is constant. Refer to Figure 3-4.

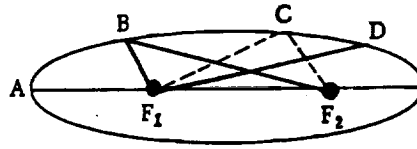


Figure 3-4. An ellipse where $BF_1 + BF_2 = CF_1 + CF_2 = DF_1 + DF_2$

2nd Law: "A line joining the planet and sun sweeps over equal areas in equal time intervals, regardless of the length of time." Therefore, equal areas are covered in the same time for a given planet. In Figure 3-5, note that area 1 = area 2, when the time to travel arc AB equals the time to travel arc CD. Since the radius vector sweeps out equal areas in equal times, planets travel faster when they are closer to the sun and slower when they are farther away from the sun. The distance AB is greater than CD, but the time interval is shorter. The distance CD is smaller than AB, but the time interval is longer.

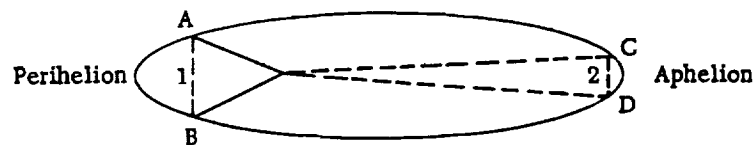


Figure 3-5. Illustration of Kepler's Second Law of Planetary Motion, with the closest point to the sun (perihelion) and farthest point from the sun (aphelion) included.

3rd Law: "The Square of the time of a planet's revolution is proportional to the cube of its average distance from the sun." Using T for time, D for distance, and k for a proportionality constant, we arrive at the formula:

$$T^2 = kD^3$$

In this formula, k is the same for all planets, namely, $1^2 \text{ year}^2 / 93^3 \times 10^{18} \text{ mi}^3$ and it is different for different groups of

celestial objects (moons, stars, etc.). Using the expression above, we can illustrate its application in practical work. Assuming that the earth's time of revolution is one year, how long would it take a planet to revolve around the sun if it were four times as far away from the sun as earth?

Since: $T^2 = kD^3$

then: $T^2 = 1^2 \text{year}^2 / \cancel{933 \times 10^{18} \text{mi}^3} \times 4^3 \times \cancel{933 \times 10^{18} \text{mi}^3} / 1$

and: $T^2 = 1^2 \text{year}^2 \times 64$

therefore: $T = \sqrt{1^2 \text{year}^2 \times 64}$

or: $T = 8 \text{ years}$

It, therefore, can be deduced that the planet concerned will revolve 8 times slower than earth, or we might say that this planet has a year equivalent to 8 earth years.

It is interesting to note that the inner planets have a faster period of revolution and a slower period of rotation than the outer planets. A planet revolves faster when it is nearest the sun and slowest when it is farthest from the sun.

Questions

1. According to Kepler's Law and the data in Table 3-1, would it be correct to assume that the slower a planet revolves, the faster it rotates? Check any possible exceptions and analyze why they are exceptions.
2. Verify Kepler's Third Law using the data for planets in Table 3-1.
3. Write a sentence summarizing the essence of each of Kepler's Laws.

The phenomena called laws were discovered by man as a result of his inquisitiveness and insight. None of these phenomena, it must be remembered, were ever observed or seen by men of the earliest periods of investigation. With the discovery of instruments and apparatus that could detect celestial objects and record phenomena accurately, man was in a better position to substantiate his old beliefs and formulate new concepts.

One of the most amazing inventions which increased our faith in the ingenuity of early investigators and which has left an indelible stamp upon us, was the perfection of the telescope by Galileo Galilei (1564-1642). His greatest contribution to astronomy was the construction of the telescope and his confirmation of the heliocen-

tric concept with the discovery of the four largest moons revolving around the planet Jupiter. Galileo also recognized the rings around the planet Saturn.

As a result of Galileo's inventions and discoveries, coupled with the innovations of modern astronomers, we have been able to pierce some of the innermost secrets of our solar system. We have been able to fit into a gigantic puzzle many pieces of astronomical information that otherwise would remain unknown. But, there are many things that we do not yet know about our solar system even though we use the most advanced equipment available to us. However, the more knowledge we attain about the objects that compose this system, the better our understanding of answers to questions that might have influence upon us as earthlings in the future.

THE PLANETS

The word planet means wanderer, a name originating from the fact that the planets seemingly wandered among the so-called "fixed stars." Early man was unable to account for the abnormal motions of the five planets he knew about.

It is now understandable that the sun is not at the center of the universe. When we speak of the sun and its planets with their satellites, we speak of our solar system. Asteroids, often called planetoids, are also members of our solar system. The major planets in order of their distance from the sun are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. All of the planets have one or more moons except Mercury, Venus, and Pluto. Pluto itself is considered by some authorities to be a runaway or escaped moon of the planet Neptune. Since the planets are at such enormous distances from the sun, it is too cumbersome and tedious a task to deal with ordinary numbers, in miles, to represent their distances. Therefore, we use (as mentioned in Chapter 1) a unit called the Astronomical Unit (A. U.) which is equivalent to 93,000,000 miles, or the computed average distance from the earth to the sun.

Mercury (The Messenger of the Gods)

If we consider Pluto to be a satellite, Mercury would be the smallest of all the planets. Its mass is about one-twentieth that of the earth's and its diameter is only one-half that of our moon's. It is so close to the sun that we can see it only when it is in certain positions in its orbit, and then only shortly before sunrise or after sunset.

Mercury is too small for its gravitational attraction to hold atmospheric particles to its surface. Since it is the nearest planet to the sun, it receives about seven times as much solar energy and

radiation per unit area as does our earth. Due to this, and because so little radiant energy is reflected, the side of Mercury facing the sun must be a scorching desert too hot to support life; while the other side, which is always dark, must be extremely cold. Because Mercury's rotation period (88 days) equals its revolution period (88 days), it keeps the same face turned to the sun. There are neither atmosphere nor bodies of water on this planet. Can you give any reasons why man is not interested in landing on or inhabiting the planet Mercury?

Venus (The Goddess of Love)

Venus is the brightest of all the planets. It is called, erroneously, the morning or evening "star." Due to the fact that its mass and size approximate that of the earth's, Venus is often referred to as the earth's twin. Since a great amount of the sunlight which strikes it is reflected, it is known to have an atmosphere. In fact, great clouds surround this planet and although it is the closest planet to earth, these permanent clouds prevent astronomers from studying it in detail. However, in 1962, the spacecraft Mariner II was launched and has since relayed back information on the atmosphere and magnetic field of Venus. No conclusive evidence has been derived to date. Spectroscopic analysis indicates that there is little oxygen in its atmosphere. This indicates little vegetation, since we know that oxygen is a by-product of food manufactured by plants on earth.

Since Venus is closer to the sun than earth, it receives more radiant energy which must result in greater evaporation of water to form clouds. Temperatures on Venus may exceed the boiling point of water, and if there are great oceans of water on the surface, these could vaporize to form its dense clouds.

The rotation period of Venus is not really known; as a result, we assign periods ranging from 30-225 days for this planet to make one complete circuit on its axis.

Questions

1. What discoveries of Galileo confirmed the Heliocentric System?
2. Why is man interested in exploring the atmosphere and surface of Venus?
3. Why is it understandable that a layman calls Venus a star? How could you tell this planet from a star?
4. Contrast the physical conditions on Mercury and Venus.
5. Why does Mercury present the same face toward the sun?
6. Why does Venus shine so brightly?

Earth

This planet, which we inhabit, has a circumference of approximately 25,000 miles and a diameter of almost 8,000 miles. The earth has one satellite—the moon; but we must bear in mind that we have orbited many artificial satellites about it. The earth will be considered in more detail in Chapter 4 and in other sections of this book.

Mars (God of War)

Mars is more like the earth than Venus. It has two moons that revolve about it—Phobos and Deimos. Phobos is only ten miles in diameter; it revolves at a distance of 3,700 miles from Mars, and makes one revolution every seven hours and thirty-nine minutes. It rises in the west every eleven hours and seven minutes, and sets in the east. Consequently, it may rise twice in one night. Deimos, on the other hand, rises in the east and sets in the west; it is farther from Mars than Phobos and takes more than a day to revolve around the planet.

Mars has seasons like the earth. It also has an atmosphere which probably contains water vapor and small quantities of oxygen. There are greenish areas and immense polar caps that are visible on Mars in certain seasons. It is probable that the temperature on this planet, which is about 80°F at the equator, is warm enough to support some form of life. Many investigators claim that there are canals on the surface of Mars that conduct water from the polar caps to the warmer parts of the planet. It is called the red planet because regions on its surface, often called desert areas, appear red from earth. Regardless of the interpretations of observations, there are definite markings on Mars and in 1965 a Mariner spacecraft relayed data and pictures of a closeup view of the planet.

Asteroids (Planetoids)

In 1801, the Italian astronomer Piazzi, while searching for another planet predicted by Bode to be between Mars and Jupiter, found a little planet he named Ceres. Its diameter is less than 500 miles and it is found 2.8 A. U. from the sun. Of all the asteroids, more than fifteen hundred whose orbits have been determined, Ceres remains the largest. Many of these have fanciful names representing the Greeks, pet dogs, and various institutions of learning. One of the most interesting of these small planets, Eros, comes quite near the earth—about 16 million miles—and is used as a yardstick in astronomical calculations. It is possible that these small bodies are fragments of larger bodies that have disintegrated, or even material that did not condense into a larger planet when the solar system originated. The total number of asteroids has been

estimated to be about 40,000 with most of them being located in elliptical orbits between Mars and Jupiter.

Jupiter (God of the Universe)

Jupiter is the largest planet in our solar system. Its density is about $\frac{1}{4}$ that of the earth's but its mass is 318 times the mass of the earth. From this it can be deduced that Jupiter's volume is much larger than that of the earth and its diameter is more than eleven times as great.

This planet appears as a morning or evening "star," but it shines less brilliantly than the planet Venus. Like Mars and Saturn, it may also appear as a midnight "star." Jupiter's day is about ten hours long. This rapid rotation of such a large planet results in an appreciable bulging at its equator.

Since Jupiter is so far away from the sun, it receives relatively little radiant energy. Its surface temperature is about -212°F and ice has been detected on this cold planet.

Jupiter has twelve moons, four of which are visible with a small telescope. These four satellites range in size from that of our moon to a size larger than that of the planet Mercury. The other eight satellites are quite small, ranging from twenty-five miles to one hundred miles in diameter, and they can be detected only by using larger telescopes. The two outermost moons are remarkable in that they revolve in a direction counter to that of all the planets and most of their satellites. This east to west motion is relatively rare in the universe, for most motions are west to east. It has been suggested that these two moons were asteroids that came close to Jupiter, so close in fact that they were unable to escape Jupiter's large gravitational attraction for them. Jupiter is also believed to be shrouded by clouds like the planet Venus. Due to its rapid rotation period, it has a striped appearance which is produced by convection currents.

Saturn (God of Time)

The second largest planet, Saturn, has a diameter nine times that of earth, but a density less than that of water (less than 1). Like Jupiter, its day is short, its year long, and it bulges at the equator. Its temperature is lower than that of Jupiter, as would be expected. One of the most beautiful of celestial observations is to behold the rings of Saturn. This series of three rings, beginning about 7,000 miles from the surface of the planet and extending outwards about 41,000 miles, has been estimated to be more than ten miles thick. Consisting of rocks, dust, and solid ice, these rings resemble asteroids and they are thought to be composed of material that didn't condense into moons. They might also have resulted from material that remained from a moon broken up by tidal action.

Saturn has nine moons, the largest of which, Titan, is larger than our moon and has an atmosphere. The smallest moon, Phoebe, is only 150 miles in diameter and was the first moon of any planet whose direction of revolution was observed to be counter to that of the planet.

Uranus (Father of the Titans)

On the night of March 13, 1781, Sir William Herschel discovered the planet Uranus by accident. In his honor, this planet is often called Herschel.

The atmosphere of Uranus is similar to that of Jupiter and Saturn with ammonia and methane in its composition. Very little is known about this planet which was once thought a star. It appears greenish in color and even shows faint markings of cloud belts. Its rotation period is believed to be 10.7 hours as determined by its large bulge at the equator. It is 15 times as massive as the earth and its temperature is only -300°F . Two strange, but interesting, features of Uranus are that it rotates east to west and its equator is tilted at almost 98° to the ecliptic plane. Its five moons revolve in the direction that the planet rotates.

Neptune (God of the Sea)

The laws of Sir Isaac Newton enable man to compute the paths of celestial bodies with a great deal of accuracy. The planet Uranus followed its predicted path until 1831, when its deviation began to be enough for astronomers to observe. By 1841, the discrepancies were so great that one of two conclusions had to be drawn; either Newton's Laws were incorrect or there was an unknown body influencing the path of Uranus. Two mathematicians, John Adams in England and Joseph Leverrier in France, working independently, calculated the position of this unknown body. In 1846, Leverrier wrote the German astronomer Johann Galle telling him the exact location of the new planet. After a half-hour's search, Galle discovered the planet Neptune less than a degree distant from the predicted position. This was a great triumph for Newton's Laws and it increased man's belief in the postulate that his universe is one of cause and effect.

Neptune is called Uranus' twin and is the third largest planet in our solar system. Methane is the most abundant gas in its atmosphere as is indicated by its greenish color. It has two satellites, one of which rotates east to west.

Pluto (God of the Underworld)

In 1930, the world was amazed by the announcement of a new planet named Pluto. Even after the discovery of Neptune, astrono-

mers were still detecting disturbed motions of Uranus that could not be accounted for. Various investigators set themselves to the task of predicting the position of another planet. Perceval Lowell was one of the most constant searchers, and it is a tribute to his memory that, although the discovery was not made until after his death, his calculations made the discovery possible. The image of the planet was found on a photographic plate by a young assistant named C. W. Tombaugh at the Lowell Observatory. Actually the planet is very faint and very little is known about it. It is about one half the size of the earth and its atmosphere is frozen. Since Pluto would have to be considered an erratic "planet," some astronomers call it an escaped moon of the planet Neptune. Pluto also revolves extremely slowly, only 3 mi/sec.

Table 3-1 is an analysis of data which describes each planet and its place in our solar system. Figure 3-6 is a model of our solar system.

Questions

1. Why are Venus and Mars called the earth's twins?
2. List unique features of each planet.
3. What features on Mars suggest the presence of life? Which features discourage life as we know it on earth?
4. Which planets show phases like the moon? Why?
5. How many pounds would an astronaut weigh on Jupiter?

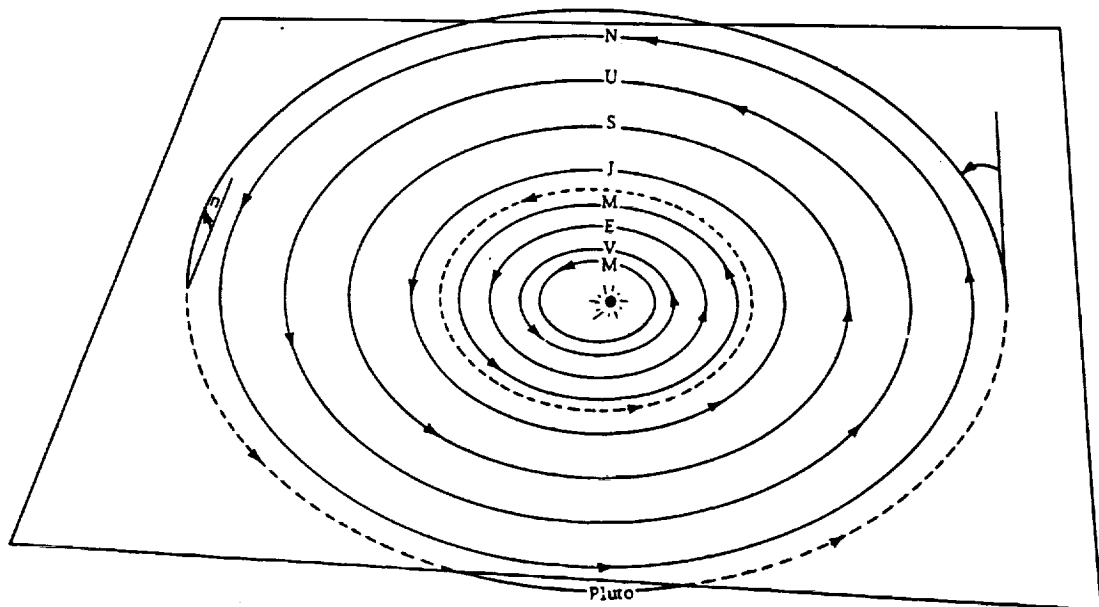


Figure 3-6. Model of our Solar System.

TABLE 3-1
Data for the Planets in Our Solar System

Planet	Mean Distance From Sun		Mean Diameter (in miles)	Mass (Earth =1)	Period of Revolution	Period of Rotation	Number of Moons
	Millions of Miles	A.U.					
Mercury	36.0	0.4	3,000	0.05	88 days	88 days	0
Venus	67.2	0.7	7,600	0.8	225 days	(225 days?)	0
Earth	93.0	1.0	7,913	1.0	365 1/4 days	23 ^h 56 ^m	1
Mars	141.6	1.5	4,200	0.11	687 days	24 ^h 37 ^m	2
Jupiter	483.3	5.2	86,800	318	12 years	10 ^h	12
Saturn	886.2	9.5	71,500	95	29.5 years	10 ^h 14 ^m	9
Uranus	1783.0	19	29,400	15	84 years	10 ^h 8 ^m	5
Neptune	2794.0	30	28,000	17	165 years	15 ^h 8 ^m	2
Pluto (?)	3671.0	39.4	3,700	(0.1?)	248 years	(6 days?)	0

COMETS, METEORS, AND METEORITES

For centuries, man has gazed into the sky with awe and wonder. Some of the objects and phenomena which he observed instilled within him a deep desire to delve into the mysteries of outer space; and in so doing, he was able to use the information he obtained to foster progress on his planet—earth. This information also assisted him in carrying out his daily tasks. However, not all the celestial phenomena that man observed had a wholesome effect, and they implanted within him a deep fear when they manifested themselves or were observed. Such celestial objects as comets, meteors, and meteorites were not fully understood by early man, and as a result, he looked upon them as signs of great disaster or chaos both in the heavens and on the earth.

Modern man soon learned not to fear these celestial phenomena as had his predecessors. Instead, he investigated them as to their cause and effect, and he began to use the information so obtained to assist him in further studies of the universe. Through these scientific investigations, modern man has been able to assign evidence and present plausible conclusions as to the WHY? the WHERE? the HOW? and the WHEN? of these once feared comets, meteors, and meteorites. To be sure, all of the needed information about these celestial bodies is yet unknown, however, today man is better able to cope with the appearance of them and his personal fear has been transformed into a deeper desire to study more intricately the beauty and wonder that are manifested by these phenomena. *

Comets

Prior to the invention of the telescope, only very large comets could be seen with the unaided eye. Records show that only 400 comets were noted before 1600. Since then, the number of comets seen yearly has increased with the increase in the size of telescopes. About 500 comets have been recorded since 1600. Approximately five are discovered yearly, although in 1925, eleven were observed. Most comets are faint objects which are visible only in larger telescopes.

When a comet is first observed with a telescope, it appears merely as a spot of light, sometimes with a blurred or fuzzy appearance. As it gets nearer, the blurred outline becomes more clear, until eventually a tail develops; while this is being observed, the head of the comet decreases in size. As the comet approaches the sun, the tail increases in length and always points away from the sun. The result of this is that as the comet is moving away

* Although all of the phenomena are not members of our solar system, they are discussed in this chapter because they are closely associated with our solar system.

from the sun, the tail streams out in front of it. As the comet moves farther away into space, the tail decreases in size until it finally disappears.

There are two parts which make up the head of a comet; the nucleus which is a small bright center, and the coma which is blurred and hazy in structure. The coma of the head surrounds the nucleus.

The volume of a comet is very large. The diameter of the nucleus rarely exceeds 500 miles, however, the diameter of the coma ranges from 30,000 to 150,000 miles. Frequently, the diameter of the coma is as large as 1 million miles. The largest part of a comet is its tail which ranges from 5 million to 100 million miles in length.

Although the volume of a comet is enormous, the amount of material composing the comet is very small. This is manifested by the great amount of deflection in its original path caused by the gravitational pull of a large planet when the comet passes near one.

Astronomers are certain that the nucleus of a comet is not solid. Rather, they believe it to be a mixture of dust particles and gas, containing little pieces of matter about the size of pebbles and stones. The coma is composed of very thin gaseous material and tiny dust particles. These are so thin that stars can be seen through the coma with very little loss of brightness. The material which composes the tail is even thinner than that of the nucleus or coma. It is so thin that a vacuum tube contains more particles per cubic inch than does the tail of a comet. As evidenced by its behavior, astronomers believe that the tail, is composed of gaseous material driven out of the comet's head by pressure of the sun's rays. It is continually being produced by this gaseous material and at the same time dissipated into outer-space.

Sometimes the tail of a comet appears to break in two or explode. Its shape is changed almost instantaneously. Often, a large piece of the tail appears to break off and disappears in space. Frequently, when a comet is near the sun, it develops two or three tails.

Formerly, astronomers believed that comets entered our solar system from far off regions of outer-space. However, they now concede that some comets may be members of our solar system. One theory proposes that they are composed of tiny pieces of material erupted from the sun or some major planet after the origin of the solar system. A second theory suggests that comets are pieces of material that were picked up by the solar system some 10 million years ago by passing through a nebula. Because they are composed of light chemical elements and shine mostly by their own light, comets are also thought by some astronomers to be disintegrated

stars. Scientists estimate that the solar system contains 1 million comets.

A majority of comets have such large orbits that they are seen only once in thousands of years. However, many comets have small orbits and, therefore, are seen quite often. The most famous of these comets is Halley's Comet which was named for Edmund Halley, a great British royal astronomer. Halley's Comet appeared in 1682, and Halley and his friend Sir Isaac Newton, calculated its orbit on the basis of laws proposed by Newton in his book entitled Principia. Halley compared the calculations obtained for the orbit of this brilliant comet with the calculations of the orbits of former brilliant comets. He found that the orbit of his comet was similar to those of the comets of 1531 and 1607. He concluded that these three comets were the same and that it appeared in view approximately every 75 years. Halley predicted that this comet would return in 1758, and although he died 17 years before its return, his prediction was verified. It has since returned in 1835 and 1910, and is due to return in 1985.

About 36 comets belong to a group that is known as Jupiter's Family. Some astronomers believe that they have been "captured" by the planet Jupiter. They passed near this planet and had their orbits changed by its gravitational pull. Since then, these comets revolve in small orbits, one end of which is near the sun and the other near the orbit of Jupiter. We see these comets every three or eight years. However, they seem to be dissipating their mass

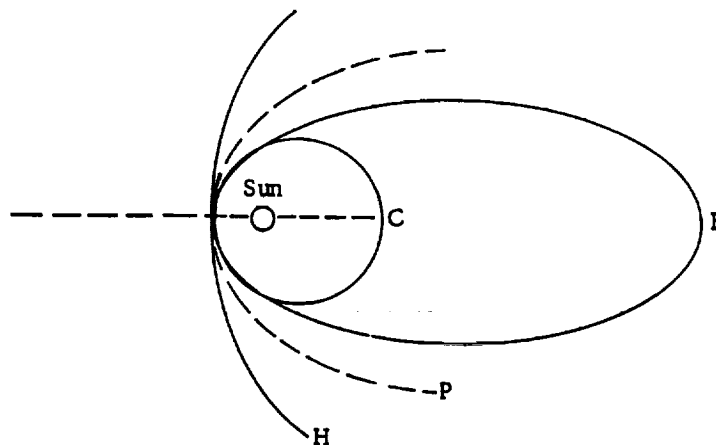


Figure 3-7. The possible orbits of celestial bodies. If a comet is in an elliptical orbit (E), it will reappear in a definite time interval. A comet in hyperbolic orbit (H) will appear only once in our solar system. Comets have no true parabolic orbits (P) to the sun. Circular orbit (C) is the fourth possible orbit of a celestial body.

rapidly and are fainter and fainter each time they return. Scientists believe that the damage to these comets is due to their nearness to the sun and other planets. Biela's Comet, which is found in Jupiter's Family, was observed in 1772, 1806, 1826, and 1832. When it returned in 1846, it was observed to break into two parts. The two halves were seen in 1852 for the last time. Another comet called Taylor's Comet split into two parts in 1916.

Meteors (Shooting or falling stars)

Everyone has seen "shooting or falling stars" as they move through the sky at night. They are not stars at all. They are pieces of material that are found in outer-space and which descend to the earth. If we observe the heavens on a moonless night, we can sometimes see as many as sixteen per hour fall to the earth. It is estimated that several million of these "pieces of matter" fall into the earth's atmosphere every 24 hours.

Astronomers do not know the true origin of this cosmic rubbish. Several theories have been presented regarding its source. It may be due to matter that our solar system picked up by passing through a nebula, or it may be matter that remained after the planets were formed. If the theory regarding the formation of the planets from material pulled out from the sun is correct, then this meteoric material more than likely was pulled out of the sun at the same time.

These pieces of matter remain invisible until their path crosses that of the earth. As they enter the earth's atmosphere, friction causes them to grow so hot that they first melt and then vaporize. The fiery trail of the "shooting or falling stars" is the trail of the incandescent vapors as these bits of matter are consumed. These erroneously named "stars" are known to the astronomer as meteors.

Meteorites

Many times a large meteor enters the earth's atmosphere and is not entirely burned up by frictional heat. The remaining piece of material which strikes the earth's surface is called a "meteorite."

Meteorites are of great significance to the astronomer because they are man's only tangible connection with outer-space. The astronomer can study the other celestial bodies merely by their light, but they can handle a meteorite and analyze it chemically. Sometimes the material which strikes the earth is but a single piece; frequently it consists of a number of fragments. In 1869, the number of meteorites which fell at Pultusk was estimated to be 100,000. Most of them were very small though. The largest known meteorite was found by Admiral Peary at Melville Bay, Greenland. This meteorite weighed 36 1/2 tons.

The meteorites can be divided into three types. One that is known as the stony meteorite is composed of crystalline rock. It consists almost entirely of a dark, heavy rock known as "peridotite." Another, that is known as the iron meteorite, is almost entirely iron. The iron in it, however, exhibits a crystalline structure which differs from the iron found on earth. The third type, known as the iron-stony meteorite, is a mixture that is made up chiefly of iron and peridotite.

In the Arizona desert, there is a great crater about 4,000 feet in diameter. Its walls rise 150 feet above the desert. Its interior sinks several hundred feet below the general level of the desert. Thousands of meteorites have been found near this crater, and pieces of meteoric iron have been dug out of the walls of the crater. Astronomers feel certain that this huge crater is the result of a great meteorite or group of meteorites which struck the earth on this spot a thousand or more years ago.

Meteoric Showers

Frequently, a meteoric shower occurs. The entire sky will seem covered with "shooting stars." Some of these meteoric showers are yearly events. Due to this evidence, astronomers have deduced that there must be a number of swarms of meteors moving in regular orbits around the sun.

A meteoric shower occurs when the earth, while in its orbit, cuts across the orbit of a swarm of meteors. Some of the swarms are most likely comets that have disintegrated. The orbit of one meteoric swarm, known as the Andromedes, has been identified with that of Biela's Comet (this was the comet which split into two parts in 1846 and disappeared after 1852).

ZODIACAL LIGHT

On a clear, moonless night, just after twilight has ended, a faint streak of light can be seen in the west, stretching up from where the sun has disappeared. This is known to astronomers as the "Zodiacal Light." The streak of light may possibly result from sunlight being reflected from a mass of thin, gaseous material which surrounds the sun in a sort of lens-shaped formation.

Questions

1. What is the origin of comets?
2. What causes the zodiacal light?
3. Why are meteors erroneously called "falling stars?"

4. How can a study of meteorites assist man in his space explorations?
5. Differentiate between a meteor and a meteorite.

Activities

Multiple Choice: For each of the following questions, select the number representing the most complete answer and write it in the proper place on the answer sheet.

1. The word that best describes the planets is: 1. Descender, 2. Wanderer, 3. Philanderer, 4. Tempster.
2. The approximate center of the universe is: 1. The Moon, 2. The Earth, 3. The Planets, 4. The Sun, 5. None of these.
3. Which group of planets have no satellites? 1. Venus; Earth, 2. Venus; Mercury, 3. Jupiter; Uranus, 4. Neptune; Saturn.
4. Kepler modified the Heliocentric System by showing that the planetary orbits are: 1. circles, 2. ellipses, 3. equidistant apart from one another, 4. combinations of circles and epicycles.
5. Saturn's rings: 1. could be material that failed to condense into satellites, 2. could have originated from the disintegration of satellites, 3. 1 and 2 are plausible theories, 4. Saturn has no rings.
6. The planet that is known as the Messenger of the Gods is: 1. Mercury, 2. Mars, 3. Uranus, 4. Saturn.
7. Which one of the following planets can be seen during the daytime? 1. Mercury, 2. Pluto, 3. Neptune, 4. Venus.
8. A planet that is 4 times farther from the sun than earth would revolve ____?____ than the earth. 1. 4 times faster, 2. 4 times slower, 3. 8 times slower, 4. 8 times faster.
9. . . . and its day should be ____?____ than earth's day. 1. equal to, 2. shorter than, 3. longer than.
10. . . . and the preceding was computed by using: 1. Kepler's 3rd Law, 2. Newton's 2nd Law, 3. Newton's Law of Gravity.
11. Mars: 1. has longer seasons than earth, 2. rotates about every 24 hours, 3. has an atmosphere, 4. all of these.
12. Which one of the following planets receives the greatest amount of solar radiation? 1. Mercury, 2. Venus, 3. Mars, 4. Earth.

13. Planets shine because they: 1. emit light, 2. are illuminated by nearby stars, 3. reflect light reaching them from the sun, 4. reflect light reaching them from the earth.
14. The number of miles that represents the approximate distance of the earth to the sun is called a(n): 1. Light year, 2. Parsec, 3. Astronomical Unit, 4. Functional Unit.
15. The Heliocentric Theory was proposed by: 1. Kepler, 2. Copernicus, 3. Tycho Brahe, 4. Galileo.
16. The Almagest was the work of: 1. Copernicus, 2. Tycho, 3. Ptolemy, 4. Galileo.
17. Which one of the following groups are asteroids? 1. Earth, Venus, Mars, 2. Ceres, Achilles, Eros, 3. Ceres, Jupiter, Achilles, 4. Pluto, Eros, Ceres.
18. Which one of the following celestial bodies is used as a yardstick in astronomical calculations? 1. Achilles, 2. Pluto, 3. Uranus, 4. Eros.
19. The first moon whose direction of revolution was observed to be counter to that of its mother planet was: 1. Eros, 2. Achilles, 3. Titan, 4. Phoebe.
20. The planet Herschel is also called: 1. Jupiter, 2. Mars, 3. Uranus, 4. Neptune.
21. The planet Neptune was discovered by: 1. Tombaugh, 2. Newton, 3. Herschel, 4. Galle.
22. The man whose calculations made possible the discovery of Pluto was: 1. Leverrier, 2. Adams, 3. Lowell, 4. Galle.
23. One astronomical unit is equal to 93,000,000 miles. If Mercury is 0.4 A.U. from the sun and Venus is 0.7 A.U. from the sun, the number of miles that separates the two planets is: 1. 310,000, 2. 3,100, 3. 31,000,000, 4. 310,000,000.
24. The circumference of a circle is equal to $2\pi r$ or πD . If the radius of the earth is 4,000 miles, its circumference is: 1. 8,000 miles, 2. 2500 miles, 3. 80,000 miles, 4. 25,000 miles.
25. The diameter of the planet Jupiter is 87,000 miles, and that of the sun is 864,000 miles. The number of times which the sun is larger than Jupiter is: 1. 100, 2. 10, 3. 12.0, 4. 8.0.
26. Light travels at the speed of 186,000 miles per second. The time which it takes a ray of light to travel from Mars to the sun, a distance of 141,500,000 miles, is: 1. 760.7 sec., 2. 76.07 sec., 3. 7.607 sec., 4. .7607 sec.

27. A beam of light traveled from the sun to the earth in 500 seconds. The velocity of this beam of light, if the distance from the sun to the earth is 93,000,000 miles, is: 1. 86,000 miles per second, 2. 18,600 miles per second, 3. 186,000 miles per second, 4. 860,000 miles per second.
28. Neptune is about _____ times as far from the sun as earth:
1. .3, 2. 300, 3. 3, 4. 30.
29. The mass of Mars is _____ earth's mass: 1. 1/10, 2. approximately equal to, 3. twice, 4. 9 times.
30. One year on Jupiter is equivalent to _____ earth years:
1. 1, 2. 10, 3. 12, 4. 20.
31. Motions within our solar system are predominantly:
1. East to West, 2. West to East, 3. North to South, 4. South to North.
32. A day on Uranus is _____ a day on Saturn: 1. 6 hours longer than, 2. 6 hours shorter than, 3. 6 minutes longer than, 4. 6 minutes shorter than.
33. The asteroids are mostly between the orbits of: 1. Mercury and Venus, 2. Mars and Earth, 3. Mars and Jupiter, 4. Jupiter and Saturn.
34. Which are called (incorrectly, of course) "falling stars"?
1. comets, 2. asteroids, 3. meteors, 4. planetoids.
35. A noted comet with a 75 year period was discovered by:
1. Galileo, 2. Ptolemy, 3. Kepler, 4. Halley.

Matching: Match the numbered items on the right with the lettered items on the left. Place the numbers of your answers in their proper places on the answer sheet.

- | | |
|--|------------|
| I. A. Shortest period of revolution | 1. Saturn |
| B. Largest planet | 2. Mars |
| C. Famous and controversial canals | 3. Mercury |
| D. The ringed planet | 4. Venus |
| E. Shortest year | 5. Jupiter |
| F. Longest year of the above | 6. Uranus |
| G. Revolution period equals rotation period | 7. Neptune |
| H. One pole perpetual day; other pole perpetual night; tilt 98° | |
| I. Rotation period <u>unknown</u> due to dense cloud surrounding it | |

- J. Nearest planet to earth
- K. Longest day in the list
- L. Has the largest number of moons
- M. Christmas would occur once a day
- N. Visible pole caps
- O. Smallest planet
- P. Shortest day of the above
- Q. Deimos and Phobos are its moons
- R. One of its moons definitely has an atmosphere
- S. Keeps the same face to the Sun
- T. 98° tilt
- U. Where you would weigh the least

- | | |
|--|---|
| II. A. Planets revolve around the sun in elliptical orbits | 1. Geocentric System only |
| B. Stars are fixed | 2. Heliocentric System only |
| C. The sun revolves around the earth every 24 hours | 3. Geocentric and Heliocentric Systems |
| D. The sun is the center of the solar system | 4. Neither Geocentric nor Heliocentric System |
| E. Motions of planets are in perfect circles | |
| F. The earth is in the center of the Universe | |
| G. The moon revolves around the earth | |
| H. There are six planets | |
| I. The earth rotates on its axis | |
| J. The central body is not in motion | |

True-False: In the proper places on your answer sheet, place a "T" for the statements that are true and an "F" for the statements that are false.

1. Brahe did not believe the earth itself was in motion.
2. Copernicus formulated the Heliocentric concept with the aid of a telescope.

FAYETTEVILLE STATE UNIVERSITY

TEACHING INTEGRATED MATHEMATICS AND SCIENCE FOR MIDDLE GRADES

The Moon and Eclipses

CONCEPTS:

The moon shines by reflected sunlight, therefore, only that portion of it which faces the sun is illuminated.

We see the illuminated portion of the moon from various positions (angles) during the month. The changes in the appearance of the moon at these times account for its phases.

The moon's rotation period approximates its revolution period. For this reason, we see only one side of our satellite.

An eclipse of the sun occurs when the moon crosses the orbital plane while in, or near, new phase. An eclipse of the moon occurs when the moon crosses the orbital plane while in, or near, full phase.

INTRODUCTION

Our planet earth has only one natural satellite—the moon. The cycle of phases of the moon is responsible for the subdivision of the year into months. Superstitious beliefs regarding the moon have been and still are held by many people, but we know these to be without foundation in fact. It is known, and can be demonstrated, that the moon does have certain profound effects on the earth. Among these are its influences on the precession of the equinoxes and the subsequent shortening of the tropical year, the production of tides, and the slowing down of the earth's rate of rotation. Next to the sun, the moon is the brightest and apparently largest object in our sky. However, careful examination leads us to understand that the moon is not a very large or very bright object.

George Darwin proposed that the earth and moon were once a single body which broke into two parts due to a fission process resulting from the sun's tidal forces. As a result of this catastrophe,

the Pacific Basin represents the scar in the earth's crust from which the moon material was extracted. Others who totally reject this hypothesis have found no way possible for a separation of this type to have occurred. Regardless of its origin, however, astronomers do concede that the earth and moon have been much closer together.

Questions

1. Upon what basis do we divide the year into months?
2. List some influences which the moon exerts upon the earth.
3. Describe Darwin's theory regarding the origin of the moon.
4. Why would the moon seem very large to an observer on earth who compares its size with that of other celestial objects?

DESCRIPTION OF THE MOON

The moon is very hot at times, and very cold at other times; it is a lifeless body found 239,000 miles from the center of the earth. At perigee, the moon is only 221,000 miles from the earth's center; at apogee this distance exceeds 253,000 miles. It is believed that 4 billion years ago, the moon was 8,000 miles away from the earth and the earth's day was then only 4 hours long. The earth's axial rotation is slowing down, and this results in a corresponding acceleration of the moon's orbital motion. The moon is receding from earth about 10 cm/month or approximately 4 inches/month.

The moon's diameter is approximately $\frac{1}{4}$ that of earth's (2,160 miles) and its gravitational attraction is only $\frac{1}{6}$ that of earth's. To escape from the moon, a velocity of $1\frac{1}{2}$ mi/second is necessary compared to 7 mi/second to escape from the earth.

There is little or no atmosphere on the moon and for this reason we see its surface very plainly. The negligible amount of atmosphere does not imply the absence of gases such as nitrogen, neon, or krypton. Shadows are very black and distinct; there is no twilight or half-light on the moon. There is either dazzling light or total darkness. Some light, however, is reflected from the earth and reaches the lunar surface. From the moon, the earth and its phases would appear about four times as large as the moon appears to earth. If observations were made from the front side of the moon, the earth would be in the sky day and night. From the back side, the earth could not be seen.

In regard to the temperature on the moon, in the sunshine it is very hot, reaching 212°F at noon; but at sunset, the temperature would hover around 14°F . Midnight temperatures could reach -243°F which is the temperature of dry ice. Average low readings

would range in the vicinity of -109°F . Because there is neither moisture nor appreciable atmosphere on the moon, temperatures range from one extreme to the other. Sounds are impossible on the moon due to the fact that sound waves cannot travel from a propagating source to a receiving source without a medium. Communication on the moon would have to be by radio or other means.

Lunar craters, with bright streaks radiating out from some of them, are more numerous and probably more interesting than lunar seas. Thousands of these craters are known to us. Their sizes range from about 1/1000 of a mile to 180 miles. Walls surrounding some of these craters extend 20,000 feet high, with some craters having mountain peaks and ranges in their centers. Rugged mountains which reflect the lack of erosional forces as wind and weathering agents are scattered over the lunar landscape. As determined by the length of the shadows that they cast, some of these mountains are over 26,000 feet high. The number of these craters including many secondary ones has increased with pictures taken by Ranger 7 (1964) and Lunik III (1959).

There is substantial evidence that is available to us which supports two concepts relative to the origin of lunar craters. According to one of these concepts, craters resulted from volcanic activity on the moon. The other concept holds that craters were made by meteorites colliding into the lunar surface. Lunar trips in manned space vehicles will probably settle this debate.

The names of most craters derive their origin from philosophers and astronomers who have made major contributions to science. Such names as Plato, Ptolemy, Copernicus, and Kepler have already been assigned.

Some of the moon's surface features are visible to the unaided eye and have led man to describe "the man in the moon" among other versions of myths. The combination of the light and dark markings allows man to imagine many images on the lunar surface.

The dark areas were once thought to be large seas of water and are called maria, from the Latin Mare meaning sea. Scientific studies do not indicate, however, that there is water on the moon, and these regions are actually composed of smooth rocks resembling solidified lava. This material, sometimes 750 miles wide, reflects little light and by absorbing most sunlight striking it, the surface appears dark. Many beautiful names are assigned these regions, such as Mare Serenitatis (Sea of Serenity), Mare Tranquillitatis (Sea of Tranquility), and the much larger Mare Imbrium (Sea of Showers) and Oceanus Procellarum (Ocean of Sails). Since the launching of the Russian Lunik, a recent mare found on the unseen side of the moon has been named Moscow Sea.

Questions

1. What is the approximate distance of the moon from the earth? Describe its apogee and perigee.
2. Compare the size, speed, gravitational force, atmosphere, temperature, and escape velocity of the moon with those of earth.
3. Why and how does the moon shine? Why couldn't we see the earth from the back side of the moon?
4. Describe the appearance of lunar craters. How are they believed to have originated?
5. Give the origin of seas on the moon. Of what are these areas composed?
6. Give the derivation of the names of most craters.
7. How would you explain "the man in the moon?"

THE PHASES OF THE MOON

Since the moon is not a luminous body, it emits no light of its own. It reflects the sun's rays, and as a whole, is a rather poor reflector of light. The side of the moon that is turned toward the sun is always bright and the other side is always dark. This fact, coupled with the moon's motions, causes the moon to show different areas of light. These changing shapes of the lighted portions of the moon are called its phases. The time required for the moon to revolve around the earth from one phase to the next recurrence of that same phase is approximately 29 1/2 days in duration and is termed the month of the phases. Since the four phases occur during this time interval, there are about 7 3/8 days between phases. The four phases are: (1) New Moon, (2) First Quarter Moon, (3) Full Moon, and (4) Last Quarter Moon. During the two weeks following the New Moon, at which time there is no moon visible in our sky, the moon is said to wax (increase in brightness) from New Moon to Full Moon. During the two weeks following the full phase, the moon is said to wane (decrease in brightness) from Full Moon to New Moon.

There are 90 degrees of angular rotation which separate each phase of the moon. As the moon revolves around the earth and passes through its various phases, each phase has a definite time of day when it appears over a meridian of longitude on the earth. These times are illustrated in Figure 5-1.

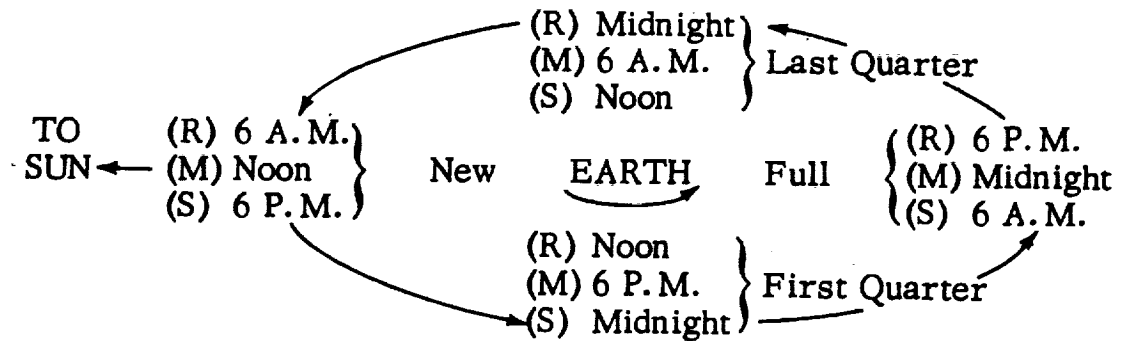


Figure 5-1. The phases of the moon where the approximate times for the moon's rising (R), appearance on a meridian (M), and setting (S) are illustrated.

Figure 5-2 is a concrete illustration of the phases of the moon as it revolves around the earth. When the moon is at position 1, we see only darkness with a faint rim of light beginning to show after a couple of days when the dark side of the moon is almost entirely towards us and its bright side is toward the sun. At position 2, the moon has swung around in its orbit until we see a little of its bright side (crescent-shaped), and at position 3, we see half the moon that is illuminated. At this position we say that it is a First Quarter Moon. At position 4, we see more of the bright face of the moon; and at position 5, we see all of the moon that is possible. When the moon is in this position, we say it is a Full Moon. After the full phase, the moon passes through positions 6, 7, and 8, showing less and less of its bright side, until it reaches position 1. Here, the sequence of the phases of the moon is begun all over again.

The moon rotates once on its axis while making a complete circuit of the earth. Due to this phenomenal characteristic of moons, we always see the same face of our moon. But, although we do not see but one side of the moon, we have been able to view about 59% of its lighted surface. We have also been able to take pictures of its dark side which reveal that it looks much like the portions that we see from earth.

Questions

1. What is meant by "phases of the moon?"
2. How many phases does the moon pass through in one month?
How many days separate each phase?
3. Describe the moon as it waxes and wanes and include the phases it passes through during these periods.
4. During what time of day does each phase of the moon appear over a meridian on earth? In what direction does the moon rotate?
In what direction does it revolve?

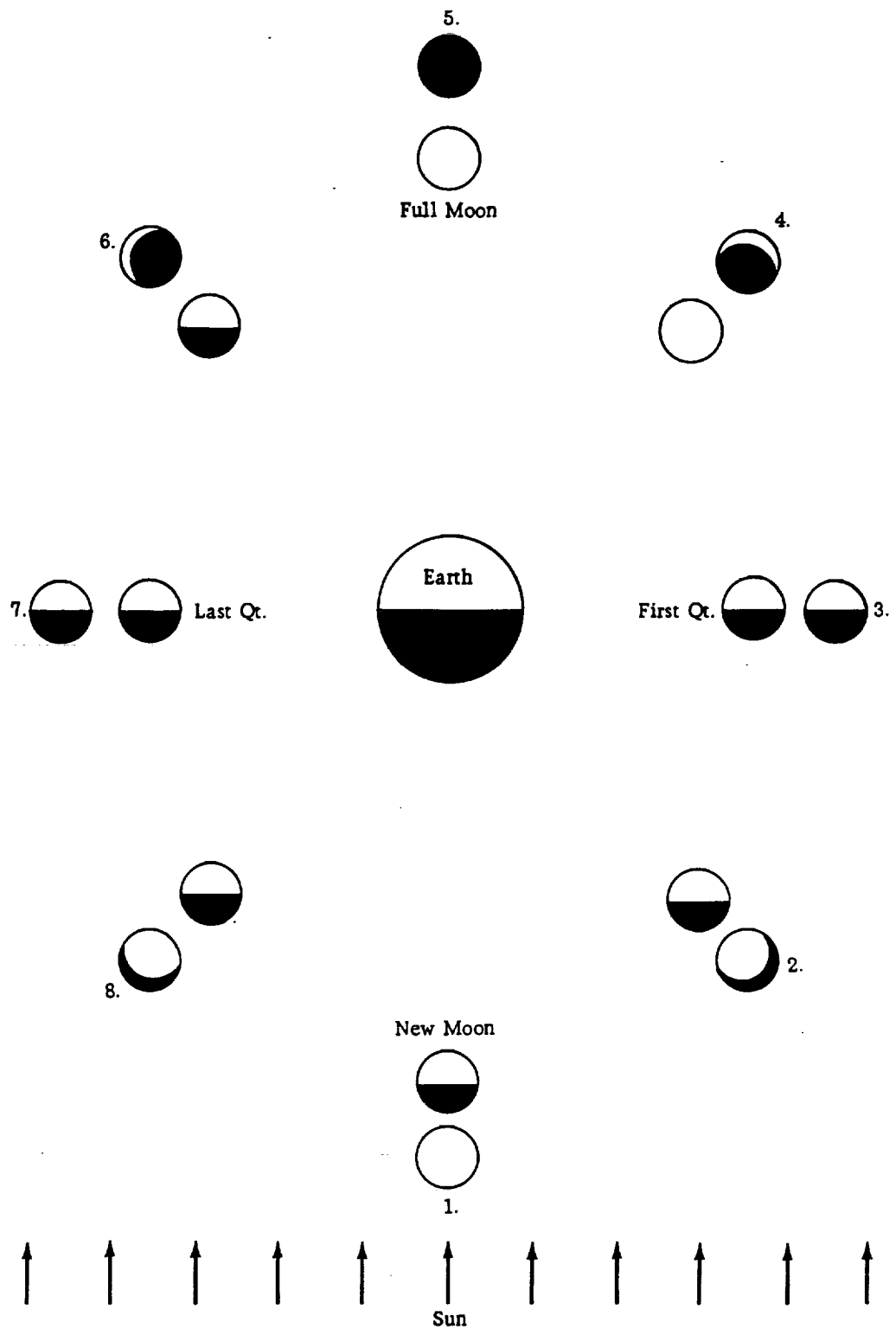


Figure 5-2. The phases of the moon.

5. What is meant by New Moon? By Full Moon? How many days separate these two phases?
6. Why do we always see the same side of the moon from the earth?

TIDES

Tides result primarily from the earth's reaction to the moon's gravitational attraction. Since the water in the oceans is more mobile than the earth's surface, a bulge in the oceans toward the moon occurs 4 times daily at approximately 6 hour, 13 minute intervals. The water on the earth facing the moon is more strongly attracted than the center of the earth or the water on the side of earth opposite the moon. This difference in the amount of gravitational attraction results in a tidal force which produces two rising bulges in the ocean waters. Land masses pass through each of the two tidal bulges as the earth rotates. The land moves toward the water which is deeper than normal. The water, in turn, moves up on the land to produce a rising tide along the coastal regions. When the land rotates past the bulge, the water recedes and the tide ebbs. Successive tides occur about 50 minutes later each day than on the previous day. During the Full and New Moons, highest tides (spring tides) occur because the moon and sun are acting together to produce a greater gravitational pull. During the First and Last Quarter Moons, the moon and sun are at right angles to each other. This means that their gravitational forces tend to counteract one another. At this time, we experience the lowest high tides, or neap tides. Figure 5-3 illustrates with vectors the reason for two high tides occurring daily on opposite sides of the earth.

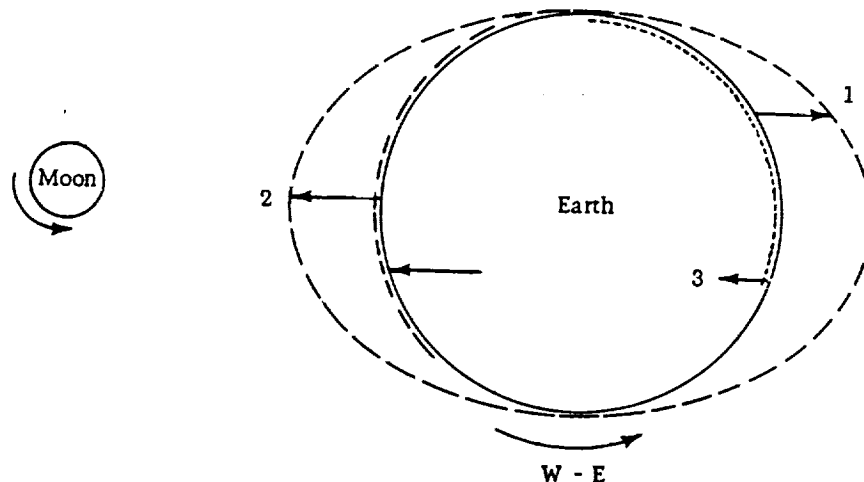


Figure 5-3. The production of tides on the earth. The long dashes (---) represent reaction of the water; the short dashes (---) reaction of the earth. The water at position 1 is not pulled with the force that water at position 2 experiences. The number 3 represents the earth's center being pulled toward the moon also.

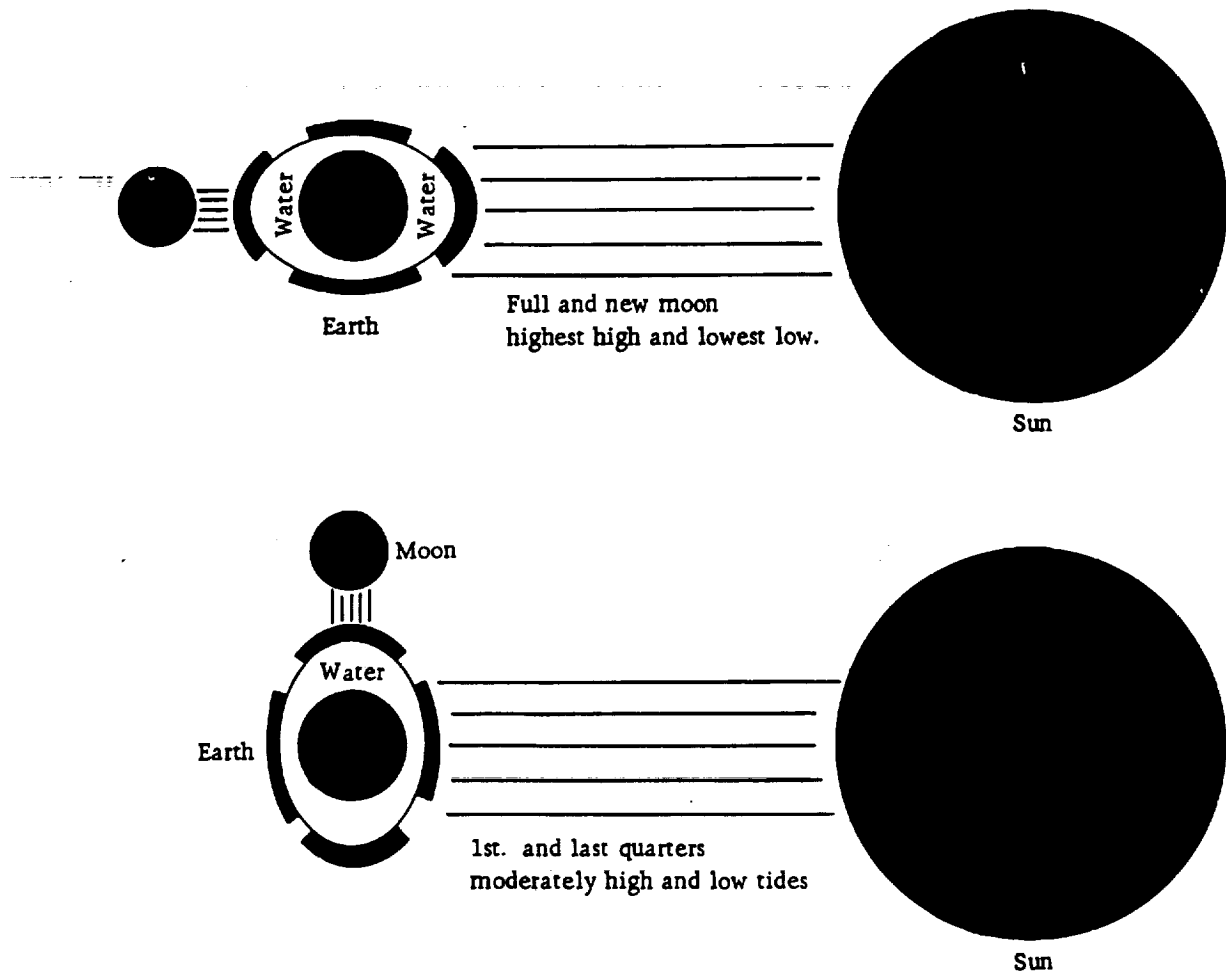


Figure 5-4. Relative positions of earth, moon, and sun at high and low tides.

Tidal friction in the water is causing the earth to slow down in its rotation. This is due to the earth's moving on its axis at a faster rate than the tides are moving. As a result, the earth drags the tides with it. The earth's day is becoming longer by 1/1000 of a second every century.

Questions

1. Explain how the tides on earth are produced. How many tides occur during each 24 hour period?
2. Define neap and spring tides.
3. Explain what happens to the water and solid portion of the earth as the moon attracts them.
4. What effects do tides have upon the earth?

ECLIPSES

The moon's orbit is inclined at a 5° angle to the plane of the ecliptic. This position is not the same from year to year, therefore, the times when eclipses occur are very different. The periods of the year during which it is possible to have eclipses are called "eclipse seasons."

The two points where the moon's orbit intersects the orbital plane are called "nodes," and they describe a circle in the orbital plane. The line joining these two points swings through 19° each year around the earth's center as pivot; it rotates in a direction opposite to that of the earth's rotation about its axis. Since an eclipse is possible only when the moon is at one of the node points of its orbit (while in New or Full phase), and since these node points revolve around the earth's center roughly 19° each year, the eclipse seasons occur earlier in successive years.

It has been previously shown that the earth revolves around the sun, while the moon revolves around the earth. All of these motions are counterclockwise. It can, therefore, be seen that the moon is sometimes between the earth and the sun, and casts its shadow toward the earth. When the moon is between the earth and the sun, we say an eclipse of the sun takes place because on some small portions of the earth, the disc of the sun is hidden from view.

In a total eclipse, the moon is directly between the earth and the sun, so that the moon's shadow falls on the earth. A total eclipse of the sun was observed in the United States in 1963. The moment of total eclipse passes very quickly, and to see this phenomenon, one must be standing on the part of the earth touched by the dark part of the moon's shadow. Should one be standing on the portion of the earth touched by the light part of the shadow, he would not see a total eclipse, but only a partial eclipse. This partial eclipse occurs in that portion of the earth on either side of the dark part of the shadow called the "umbra."

At other times, during the moon's revolution about the earth, the earth is directly between the moon and the sun, cutting off all sunlight to the moon. At such times, we say that there is an eclipse, or darkening, of the moon. All the light the moon receives is the coppery-colored glow reflected from the earth. An entire year may pass without a lunar eclipse occurring.

One might suspect that there should be two eclipses per month, one when the moon is new and another when the moon is full. However, there are several reasons why conditions for an eclipse of the moon or sun are right only a few times during a year. Total eclipses occur so seldom because:

1. The earth, moon, and sun are nearly in a straight line only twice a month. At one time the moon is between the earth

and the sun, and the other time the earth is between the moon and the sun. In the former position, there could be a solar eclipse, while in the latter position there could be a lunar eclipse.

2. The earth and the moon travel in orbits that are more oval than circular. They are so near to the sun at times that the moon's shadow is too short. The shadows then fail to reach the earth and again no total eclipse occurs. Instead, we sometimes see what is called an "annular" eclipse—a ring of the sun remains around the black disc of the moon.

From the two points above, we can deduce that it is difficult to obtain all of the conditions necessary for solar and lunar eclipses. The sun, earth, and moon must be lined up, and the lengths of the shadows must be just right. As a result, you can probably see why no more than two or three eclipses of the moon occur each year, and why a total eclipse of the sun seldom occurs.

Scientists have calculated the motions of the earth and moon so accurately that they can predict within a second or two when an eclipse is going to take place. These predictions are made years ahead of time and they have been correct. Other planets like Jupiter, Mars, and Saturn which have moons, also experience eclipses. These, too, can be accurately predicted by scientists.

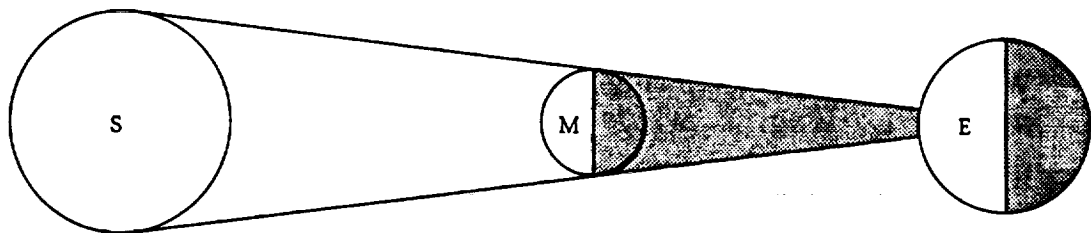


Figure 5-5. Solar eclipse.

Questions

1. Why does an eclipse appear at different times of the year?
2. When does a lunar eclipse occur? A solar eclipse?
3. What conditions are necessary in order to see a total eclipse?
4. What causes the infrequent appearance of a total eclipse?

Activities

Multiple Choice: For each of the following questions, select the number representing the most complete answer and write it in the proper place on the answer sheet.

1. The natural satellite of the earth is the: 1. sun, 2. moon, 3. planet venus, 4. North Star.
2. Which one of the following is not affected by the moon? 1. The production of tides, 2. The slowing down of the earth's rotation rate, 3. The accumulation of moisture in the atmosphere, 4. The precession of the equinoxes.
3. The number which best describes the rotation of the moon as it makes one complete revolution of the earth is: 1. 1, 2. $1/6$, 3. $7\frac{1}{2}$, 4. 2.
4. The light of the moon is provided by the: 1. earth, 2. moon, 3. stars, 4. sun.
5. If a man is able to jump six feet on the earth, how many feet would he be able to jump on the moon? 1. 6, 2. 12, 3. 24, 4. 18, 5. 36.
6. The diameter of the moon is: 1. 1600 miles, 2. 2160 miles, 3. 8,000 miles, 4. 6021 miles.
7. Which one of the following is due to the gravitational pull of the moon? 1. tides, 2. winds, 3. water, 4. rain.
8. If a man is able to take a three foot stride on the earth, the length of his stride on the moon would be: 1. 3 feet, 2. 24 feet, 3. 30 feet, 4. 18 feet.
9. The approximate distance between the earth and moon is:
1. 240,000 miles, 2. 239,000 miles, 3. 2160 miles,
4. 2,160,000 miles.
10. The greatest amount of the lunar area that can be seen from the earth is: 1. 41%, 2. 14%, 3. 59%, 4. 95%, 5. 100%.
11. The number of days that represent a month of the phases is:
1. $39\frac{1}{4}$, 2. $7\frac{1}{2}$, 3. $19\frac{1}{2}$, 4. $29\frac{1}{2}$.
12. The time of day at which one might see the Full Moon on a meridian is: 1. 6 A.M., 2. Midnight, 3. 6 P.M., 4. Noon, 5. none of these.
13. The time of day at which one might see the New Moon on a meridian is: (Choose answer from number 12)

14. If the Last Quarter Moon occurred on February 21, Full Moon should occur on or about: 1. February 28, 2. March 15, 3. March 1, 4. March 29.
15. If New Moon occurs on May 9, Last Quarter Moon should appear on or about: 1. June 2, 2. May 31, 3. June 7, 4. May 16.
16. Which one of the following would not be greater on the moon than on earth? 1. The distance a boy batted a ball, 2. The amount of atmosphere, 3. The height to which a man might jump, 4. The stride taken by a man.
17. The number of days which separate Last Quarter Moon and First Quarter Moon is: 1. 7, 2. 22, 3. 15, 4. 29 1/2.
18. The cycle of phases of the moon is responsible for the division of our year into: 1. months, 2. hours, 3. days, 4. seasons.
19. The number of degrees which separate New Moon and Full Moon is: 1. 30, 2. 15, 3. 90, 4. 180, 5. 360.
20. The number of degrees which separate Full Moon and First Quarter Moon is: 1. 180, 2. 60, 3. 90, 4. 30, 5. 360.
21. The rays of the sun are _____ by the moon. 1. refracted, 2. distracted, 3. reflected, 4. protracted.
22. Which one of the following is not a phase of the moon?
1. Last Quarter, 2. First Quarter, 3. New Moon, 4. Third Quarter.
23. When the moon increases in brightness, it is said to: 1. wane, 2. phase, 3. wax, 4. ebb.
24. When the moon decreases in brightness, it is said to: (Choose answer from # 23).
25. Which one of the following would be the best reason for a man to use a radio on the moon to communicate with other men?
1. It is too cold. 2. It is too hot. 3. It has little or no atmosphere. 4. It reflects the sun's energy.
26. In comparison with the earth, the pull of gravity on the moon is best described as: 1. 1/6, 2. 1/.6, 3. 0.6, 4. 6/1.
27. The earth is to the moon as: 1. the sun is to Venus, 2. Deimos is to Phobos, 3. Saturn is to Titan, 4. Jupiter is to the asteroids.
28. In a certain place on a certain date, the moon was over the meridian at midnight. During this time, the phase of the moon was: 1. New, 2. First Quarter, 3. Full, 4. Last Quarter.
29. In a certain place on a certain date, the moon rose at noon. The phase which it was in at this time was: (Choose answer from number 28).

30. In a certain place on a certain date, the moon set at 6 P.M. Because of the time that the moon set, it must have been in which phase? (Choose answer from number 28).
31. On a certain date the moon was in Last Quarter at 6 A.M. Greenwich Mean Solar Time. At that moment the moon was on the meridian of a place X. The longitude of place X is:
1. 30°E , 2. 90°E , 3. 60°W , 4. 15°W .
32. In a certain place and on a certain date the moon was New at noon Greenwich Mean Solar Time. At that moment the moon was on the meridian of a place X. The longitude of place X is:
1. 0° , 2. 15°E , 3. 90°W , 4. 75°W .
33. The time required to travel from New York to California is six hours. If an airplane leaves New York at 2 P.M. EST, it will arrive in California at: 1. 11 A.M. PST, 2. 7 P.M. PST, 3. 5 P.M. PST, 4. 1 P.M. PST, 5. 11 P.M. PST.
34. The moon: 1. rotates once as it revolves once around the earth, 2. is always the same distance from the earth, 3. is not visible during daylight, 4. rises at the same time every night.
35. Which statement is true? 1. The new moon is visibly the prettiest moon. 2. We see both sides of the moon from earth, 3. Pictures have been taken of all sides of the moon. 4. A lunar eclipse can occur when the moon is between the earth and the sun.

Matching: Match the numbered items on the right with the lettered items on the left. Place the numbers of your answers in their proper places on the answer sheet.

- | | |
|--|---------------------|
| A. The satellite of the earth | 1. Neap Tides |
| B. The month of the phases | 2. Deimos |
| C. A sea on the Moon | 3. First Quarter |
| D. The time between each phase of the moon | 4. 59 |
| E. When the moon increases in brightness | 5. Wanes |
| F. The number of degrees that separate each phase of the moon | 6. Nodes |
| G. When the moon decreases in brightness | 7. Lunar Eclipse |
| H. When the moon is over a meridian at noon, it is in this phase | 8. 90 |
| I. When the moon rises at midnight, it is in this phase | 9. Full Noon |
| | 10. Partial Eclipse |
| | 11. The Moon |
| | 12. 5 |

- | | |
|---|-------------------|
| J. When the moon sets at 6 A.M. , it is in this phase | 13. Last Quarter |
| K. When the moon rises at noon, it is in this phase | 14. Waxes |
| L. The amount of the moon out of its total percentage which man has been able to see | 15. 7 3/8 Days |
| M. The high tides that occur during full and new moons | 16. Mare Imbrium |
| N. These occur when the moon and sun are at right angles to each other | 17. Total Eclipse |
| O. The angle in degrees at which the moon's orbit is inclined to the plane of the ecliptic | 18. 29 1/2 Days |
| P. The points where the moon's orbit intersects the orbital plane | 19. New Moon |
| Q. When the moon is directly between the earth and the sun, this type of eclipse occurs | 20. Spring Tides |
| R. When the earth is directly between the moon and the sun, this type of eclipse occurs | 21. Mare Pacifica |
| S. When the disc of the sun is hidden from view on some small portion of the earth due to the moon being between the earth and the sun. | 22. The Sun |

True-False: In the proper places on your answer sheet, place a "T" for the statements that are true and an "F" for the statements that are false.

1. The earth has two natural satellites.
2. The earth revolves around the sun while it also rotates around the moon.
3. The moon is approximately 240,000 miles from the center of the earth.
4. The gravitational attraction on the moon is 6/10 that of earth.
5. There are gases such as nitrogen, neon, krypton, and hydrogen on the moon.
6. In the sunshine, the temperature on the moon is about -243°F.

7. Lunar craters are known to be very shallow.
8. The seas on the moon have the same amount of water as those on earth.
9. The moon shines by its own light.
10. Both sides of the moon receive the same amount of sunlight simultaneously.
11. It takes the moon 29 1/2 days to go from one phase to another.
12. If we know the time of day that the moon is on a meridian, we can find the longitude of the meridian.
13. There are 180° of angular rotation separating New and Full Moon.
14. The sun has a greater effect on the tides of the earth than has the moon.
15. There are two tides that occur each day.
16. High and low tides occur simultaneously.
17. It is difficult for a total eclipse of the sun to occur due to the fact that the earth must be directly between the sun and the moon.
18. The earth's day is becoming longer every one hundred years.
19. The nodes of the moon describe a circle in the orbital plane.
20. The moon rotates on its axis in a clockwise fashion.

Thought Questions: Record your answer to each of the following questions in its proper place on the answer sheet.

1. Why is it not possible to observe an eclipse of the sun from all parts of the earth simultaneously?
2. What reasons can be given to substantiate the fact that eclipses of the moon and sun occur less seldom than we might expect them to?
3. Why are we unable to see the moon when it is in the New phase?
4. Describe the moon as it wanes from Full to New phase.
5. Why do we always see the same "face" of the moon?
6. Contrast the path of the moon around the earth with that of the earth around the sun.
7. Describe the moon as it waxes from New to Full phase.

1

**AN ACTIVITY FROM: TIMS
TEACHING INTEGRATED MATHEMATICS/SCIENCE
FAYETTEVILLE STATE UNIVERSITY
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**Astronomical Instruments and
Scientific Measurements**

CONCEPTS:

Man has been assisted in his work of attempting to unlock the secrets of the universe through his discovery and use of various instruments. Among these are the telescope, spectroscope, and adaptation of photography to the study of celestial phenomena.

In order for man to perfect and use astronomical instruments, it was necessary for him to have a firm understanding of the characteristics of the substance which is known to him as LIGHT. He has adapted this knowledge to use in inventing many instruments and is presently seeking new instruments that will assist him in bringing the phenomena of outerspace closer to us on earth.

The innovation, adoption, and use of scientific measurement has enabled man to make progress in measuring objects of infinitesimally small dimensions and of gigantic proportions. Without the use of such measuring systems man would be at a loss for accuracy in determining the size of objects in the universe.

ASTRONOMY AND ASTRONOMICAL INSTRUMENTS

In 1609, the same year that Kepler published his famous laws, Galileo Galilei took his first look at the heavens through his primitive telescope. This was a crude instrument which he made by fitting a lens at both ends of an old organ pipe. Until that moment, no man had ever seen any more in the heavens than had the ancient Babylonians, Egyptians, or Greeks. From that instant, however, things were changed; for it was then that man began penetrating the secrets of the heavens, and a start was made toward an understanding of the true dimensions of the universe.

Galileo made one astonishing discovery after another as he gazed into the heavens with his telescope. His crude instrument

revealed mountains on the moon; the fact that the planet Venus went through phases just as the moon; and most astonishing, it revealed four tiny moons revolving around the planet Jupiter. To be exact, it was January 8, 1610 that Galileo made his astonishing discovery of four satellites of Jupiter.

In order for man to know and understand the heavens as he does today, his eyes had to be re-inforced and supplemented by many instruments other than the telescope. The spectroscope had to be invented and used; astronomical photography had to be developed and employed; the thermocouple had to be devised; and many other aids had to be perfected or adapted to astronomical use. Finally, man had to build giant telescopes—instruments without which all the other auxiliary aids would be of little value. With these objectives foremost in mind, man embarked upon his adventure into the unknown with initiative and vigor which had never before been experienced in the realm of science.

Light

For him to perfect and effectively use the instruments which he invented, it was necessary for man to have a good understanding of the properties and characteristics of the radiation we call light. He was aware of the fact that the information which he obtained about outer-space came to him through this agent, for the luminous bodies of the universe send out light waves in all directions. This characteristic enabled him to pierce into the secrets of the cosmos. Therefore, his instruments had to be devised in such a manner that their parts would gather-in the greatest amount of light rays emitted by even the most distant celestial objects.

There are three properties of light that are familiar to scientists. These properties are:

1. Light tends to travel in a straight line.
2. Light may be reflected.
3. Light may be refracted.

When light rays enter obliquely into some transparent material, such as water, or glass, they are bent or refracted. Thus, if an object is viewed through a specially shaped piece of glass (a lens), the light rays from the object may be bent in such a manner as to cause the object to appear enlarged. Ordinary magnifying glasses, as well as telescopes, depend upon this property of light. Different colors are bent, or refracted in different amounts. This makes it possible to separate white light into all of its different colors. The refraction of sunlight through raindrops to form a rainbow is familiar evidence of this property.

Light rays may produce chemical changes. Photography depends upon the chemical changes produced by light on a photo-

The Refracting Telescope

In a refracting telescope the image of the object is formed by bending or refracting the rays of light to a focus as they pass through the lenses that are arranged in the tube. The refracting telescope is the best type of instrument for visual observations and for photography where a wide field of stars is desired. The size of the refracting telescope that can be successfully built and used is, however, limited. The larger the diameter of the lens, the more difficult it is to get the glass perfectly homogeneous throughout and without optical defects. Also, the thicker the lens—it must be made thicker as the diameter is increased—the more the transmitted light rays are absorbed.

Most of the objections to larger refracting telescopes could be dealt with satisfactorily today; but larger telescopes would be very cumbersome and the cost of construction would be enormous.

The largest refractor in the world is the Yerkes telescope at Lake Geneva, Wisconsin; The Yerkes 40 inch telescope will collect about 25,600 times as much light as the eye and thus render visible stars that are this number of times too remote to be visible to the naked eye.

The next largest refracting telescope is the 36 inch Lick telescope at the Lick Observatory on Mount Hamilton in California. James Lick left three million dollars to build the telescope and observatory, which was completed in 1888. The object glass for this telescope was cast in France and polished in America.

The Reflecting Telescope

Sir Isaac Newton (1642-1727) devised the reflector telescope to eliminate the defects of the refractor. In the reflector telescope, the faint light rays from a celestial body are made to fall upon the surface of a large concave mirror at the bottom of the tube. The curved surface of the mirror converges the rays of light toward a focus; but in the more common type of reflector telescope, before reaching the focus, the rays are thrown to one side either into an eyepiece or onto a photographic plate by a plane mirror set at an angle of 45 degrees. In some instances the rays may be directed outside the tube even into adjacent rooms. There, they are analyzed or otherwise studied as desired by the astronomer.

If one should wish to use the reflector telescope to look at a celestial body, the mirror has to be supplemented by lenses. These lenses, constituting the eyepiece, act like magnifying glasses for looking at the image that is formed by the mirror.

In Ireland in 1845, Lord Rosse made the first giant reflecting telescope. He worked out the plans for the parts and with his servants built the telescope and mounted it in his park at Parsonstown.

graphic plate or film. Visible light, like other forms of radiant energy, may also be transformed into heat when the rays are absorbed by some object.

Light may be thought of as including more than the radiant energy wavelengths which can be seen. As a matter of fact, most astronomical studies do utilize visible wavelengths. But sometimes they do not. Photographic pictures may be taken with infrared rays which have longer wavelengths than any light rays which can be seen. Likewise, decided chemical effects may be produced by rays with wavelengths too short to be detected by the human eye. Everyone who has been blistered as a result of sunburn has first-hand evidence that ultra-violet waves actually reach the earth from the sun. Even such bodies as the moon and planets are studied by means of light rays. The light originates from the incandescent sun; then, after striking these non-incandescent bodies, it is reflected to the earth. Light of this nature is of tremendous assistance to man in his search for knowledge about the universe.

TELESCOPES

The telescope is mainly a device through which astronomers look to observe heavenly objects. To the astronomer, the real value of the telescope is threefold. These can be stated thus:

1. **LIGHT GATHERING POWER:** the lenses and mirrors of the telescope gather together and focus sharply the faint rays of light from the distant stars upon the prisms of spectroscopes and other instruments used for the analysis of light. In this fashion, the astronomer can learn the temperature and chemical composition of stars.
2. **RESOLVING POWER:** the telescope brings out details and makes it possible for the astronomer to accurately measure angles and distances between heavenly objects.
3. **MAGNIFYING POWER:** the telescope and time exposure enable the astronomer to take pictures of portions of the sky that are entirely invisible to the human eye. Discoveries of stars too cool to give out visible light are made by photographs taken with infrared rays. The planet Pluto was discovered in 1930, by comparing photographs of the part of the sky in which it was thought to be located.

There are two types of telescopes that are used by astronomers today. These are the refracting and reflecting telescopes. The first one that was invented was a refractor; Galileo's instrument was of this type.

glass was allowed to cool at the rate of only 1 to 2 degrees per day. This eliminated cracks and other undesirable defects in the glass.

On April 10, 1936, the mirror was shipped to Mount Palomar, California to be polished to an accuracy of "two millionths of an inch." In the final stages, polishers could not work on the mirror more than one hour per day. This was due to the fact that it was necessary to make frequent tests and measurements.

The mirror is mounted at the lower end of a 60 foot tube, and the telescope is housed in a huge revolving dome that is operated by electric motors. The tube mounting mechanism stands about as tall as a six-story building and it weighs about one million pounds. The 200,000 pound tube is mounted in a huge yoke-like mechanism whose bearings move with almost watch-like precision. The tube mounting is so delicately balanced, that it requires only 1.5 horsepower to operate it.

The powers of this telescope are enormous. It gathers as much light as a million human eyes, and with it one can see candle light at a distance of 10,000 miles. It is expected to add some hundreds of millions of stars to the number now estimated by astronomers. It will enable astronomers, when they get around to the task of studying them, to reach nebulae as far away as one billion light years (one light year is equal to 6 trillion miles). Moreover, with this telescope they can now study, in much greater detail, the 25 or 30 closest nebulae.

The world's second largest telescope is the 120 inch reflector of the Lick Observatory, located on Mount Hamilton, California. It was completed early in 1956 at a cost of \$2,400,000. The 120 inch mirror was cast in 1933 as a test preparatory to the manufacture of the 200 inch mirror for the Palomar Observatory.

Other Telescopes

Important as these huge telescope mirrors are to the study of the heavens, we must remember that astronomers must make large numbers of observations and each observation must be checked as many times as possible by different observers using different instruments which are located at different places. Other great telescopes now in use are; a 76 inch reflector at the University of Toronto, Canada; a 69 inch reflector at the Perkin Observatory in Delaware, Ohio; an 85 inch reflector at Base Lake, Michigan; and an 80 inch reflector in the McDonald Observatory on Mount Locke, Texas. There are at least 19 other large reflector telescopes, ranging from 36 inches to 62.5 inches; and more than 40 large refractors in use throughout the world.

There are no major differences between a refracting and reflecting telescope except for the objective and arrangement for

It was equipped with a 72 inch mirror, and was far larger than any other telescope built up to that time. However, when we compare it with modern telescopes, it was a very crude instrument.

In 1936, the largest telescope in existence, at that time, was constructed high upon Mount Wilson, about 5,000 feet above Pasadena, California. It is of the reflector type and has a mirror 100 inches in diameter. The four and one-half tons, 13 inch-thick mirror for this telescope was cast in France and required four years for the polishing of its surface.

The tube and mountings for this telescope are in a revolving dome that is more than 1000 feet high, and it required seven years to assemble the parts and put them together. The tube is mounted on a great hollow cylinder resting in a bath of mercury, so that, despite its enormous weight, it can be easily and quickly adjusted to take any position desired. When the telescope has been focused on a celestial object, a clock-like driving mechanism is started. As the earth rotates, the huge tube is moved in the opposite direction at the same rate and thus it is kept centered on the object that is being studied.

This huge telescope gathers in several hundred thousand times as much light as the human eye. It can capture rays of light from stars that are millions of light years away from the earth. This light is so dim that sensitive photographic plates have to be left exposed to it for hours at a time, or sometimes for several days.

The unaided eye can see a few thousand stars on a clear night. This giant reflector telescope can bring into view millions of stars at one time. Some scientists have estimated the number of stars that are visible with the 100 inch reflector telescope to be between 500,000,000 and 1,000,000,000.

As wonderful and gigantic as the Mount Wilson telescope is, it is far surpassed by the great 200 inch Hale telescope, which was completed in 1948. This massive reflecting telescope is the result of the efforts of George Ellery Hale, who died in 1938, before it was finished. It was George Ellery Hale's dream of a 200 inch telescope that brought the \$6,000,000 gift from the International Education Board, financed principally by John D. Rockefeller, Sr. This giant telescope is located on Mount Palomar, in Southern California, and it is operated by the California Institute of Technology and the Carnegie Institute of Washington, D.C. This telescope enables man to cover about eight more times of the heavens than he could before it was built.

The huge glass disk, which forms the mirror for the gigantic 200 inch telescope, was poured at the Corning Glass Works, Corning, New York, on December 2, 1934. It was removed from the oven on December 8, 1935. During the cooling process, the molten

Questions

1. Differentiate between reflection and refraction of light.
2. What familiar occurrences result from the reflection of light? From the refraction of light?
3. What is a telescope? How does a reflecting telescope differ from a refracting telescope?
4. Give several advantages and disadvantages of the types of telescopes discussed in this chapter.

PHOTOGRAPHY

We have seen that with the aid of the telescope, astronomers have been able to pierce into some of the deepest secrets of outer-space. Although the discovery and use of the telescope marked a major achievement in the science of astronomy, there are still many heavenly bodies too far distant for astronomers to study only with their eyes and the telescope. Therefore, to assist them in better understanding these distant objects, astronomers have incorporated the use of many auxiliary instruments to supplement their studies with the telescope. One of these instruments is the camera, which provides photographs to be made of distant celestial objects and their position in the universe.

By substituting a camera for the eye, the telescope becomes much more useful. The camera not only permits man to gather all of the light from stars for many hours in succession, but it also affords him an opportunity to collect permanent records, which he can study and compare over a period of time. With modern cameras, photographic plates, and precise driving mechanisms for telescopes, very long film exposures can be obtained. These photographic exposures enable man to make photographic images of objects so far off that they send very faint light rays to the earth. These would not be able to be detected clearly nor studied in detail if man merely depended upon his eye and his telescope.

In astronomy, photography has definite advantages over the mere use of the eye for observation. The main advantages can be summarized thus:

1. Photographic plates can detect very faint stars because the change in chemicals of the plate is equal to the total of light rays that reach the plates during the exposure period. In one moment, the eye sees all that it can; there is no accumulation of light on the retina of the eye.
2. Exposing a photographic plate for a long period of time produces details that would not be observable with the eye.

rerouting the reflected light. The light gathering power, resolving power, magnifying power, and the respective formulas and mountings are the same. Each type of telescope has its advantages and disadvantages; each is used for the kind of research suitable to it.

The Schmidt Telescope

In 1931, Bernhard Schmidt, of the Hamburg-Bergedorf Observatory, invented the telescope named in his honor. This telescope is an hybrid instrument, half reflector and half refractor, possessing the advantages of each. It consists of a spherical mirror and a thin lens, called a "correcting plate," which eliminates spherical aberration.

The advantages of the Schmidt telescope are that it covers a relatively large area of the sky and takes sharply defined pictures in relatively short periods of time. It will photograph an area 500 times larger than is possible with an ordinary reflecting telescope in about 1/10 of the time. The 48 inch Schmidt telescope at the Palomar Observatory is expected to advance astronomy as much as the 200 inch reflector at the same observatory. Employing the Palomar Schmidt telescope, the National Geographic Society sponsored the survey of the visible sky which was photographed on about 1,000 plates in a period of four years. This work was done using red and blue filters to give the color index of the stars.

The Radio Telescope

Intense radiation that is in the range of radio wavelengths was observed in regions of the sky where no stars had ever been detected by light telescopes. This detection of radio waves led astronomers to the conclusion that "radio" stars exist. Early in the 1950's, various types of radio telescopes were built throughout the world. Their antennae correspond to the functions of the reflector or refractor telescope. The energy that is received by them is converted into an electric current which is amplified and recorded graphically. Unsuspected clouds of hydrogen gas have been revealed by these telescopes. A giant radio telescope with a fully mobile antenna will be located at the Owens Valley Radio Observatory near Pasadena, California.

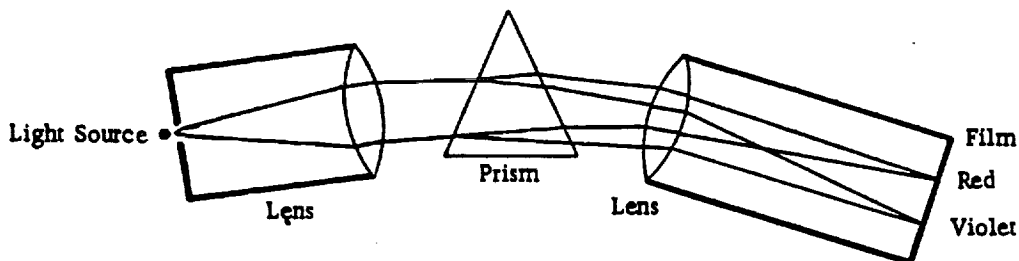


Figure 7-1. The prism spectroscope.

3. Permanent photographic records can be kept. This enables the astronomer to study specific objects from time to time, and thereby detect any changes in brightness or movement.
4. The astronomer can study photographic plates at leisure. Since some celestial bodies are above the horizon for a brief period of time, photographs of these can be studied by the astronomer at his convenience.
5. Photographs taken with a camera can be enlarged with a microscope. This is especially important to the astronomer in counting stars and studying star clusters.
6. Astronomers can study our own solar system in more detail due to the fact that planets and stars are represented by distinct images on photographic plates. The planet Pluto was discovered as a result of astronomers analyzing photographic plates.

In the field of photography, as it applies to astronomy, there are two advancements that are of particular significance. These are:

1. The development of photographic plates that are sensitive to red light and other wavelengths of light beyond the red end of the spectrum; and
2. The development of a baking process for photographic plates. By keeping the plates in an oven at 122 degrees Fahrenheit for a few days, the chemicals of the photographic plates are made more sensitive to light.

THE SPECTROSCOPE

In 1666, Sir Isaac Newton discovered the principle underlying the use of the spectroscope. He did this when he formed a spectrum by passing white light through a prism. From his experiment, Newton found that light rays are bent or refracted when they enter a prism. The visible and invisible rays form a continuous spectrum in which all of the rays originally present are separated. Man now knows that the rays are separated because those of short wavelength are bent more than those of long wavelength as they pass through the prism. If red light rays are absent in the original light rays, there will be a gap in the spectrum where red should occur, and so on for all of the visible and invisible light rays. The invisible short ultraviolet and long infrared rays, as well as the visible rays, may be photographed so that a camera can be used with the spectroscope to replace the human eye.

The spectroscope functions primarily as an instrument which disperses light rays into the various colors of which they are com-

posed. The process which is involved in this instrument is similar to the one performed by droplets of water to form a rainbow.

The dispersion of light rays into their component colors can be performed either with a glass prism or a grating. For this reason, there are basically two types of spectroscopes in use—THE PRISM SPECTROSCOPE and THE GRATING SPECTROSCOPE.

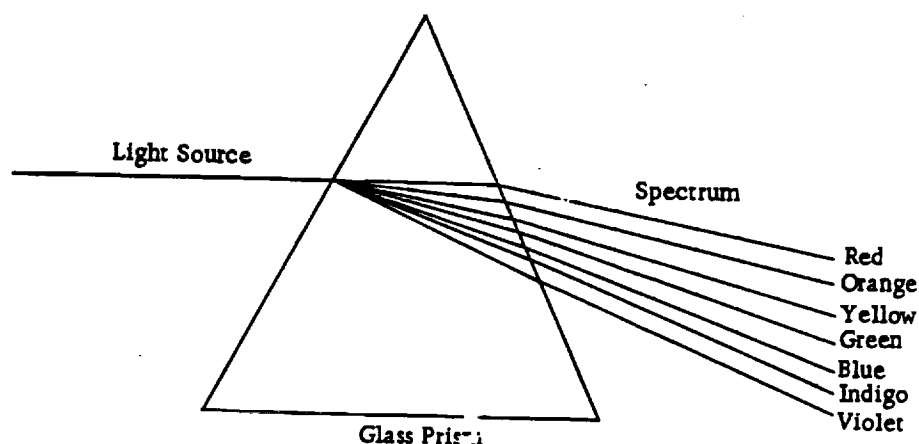


Figure 7-2. A prism dispersing light.

The Prism Spectroscope

A single ray of light will be dispersed upon entering the prism of the spectroscope into a continuous array of colors. It will be further dispersed on emerging from the prism into the air. Such an arrangement of colors is called a SPECTRUM. In the case of sunlight, the spectrum will contain all of the seven principal colors—violet, indigo, blue, green, yellow, orange, and red. All the intermediate color transitions will also be present.

In addition to the prism, the other parts of a prism spectroscope are a narrow slit, a collimator, and a telescope.

The narrow slit is the door through which the light enters the spectroscope. The slit is made very narrow to prevent over-lapping of colors in the spectrum. The narrow slit is placed at the focus of an achromatic lens that is called the "collimator," the function of which is to reroute the rays of light into parallel paths. Each parallel ray, on passing through the prism, is dispersed into the various colors of the spectrum. The task of collecting the red components of all the rays in one place is performed by the objective of the telescope; it brings together all the dispersed red components as well as the dispersed components of the other colors, and places them side by side. The eye, looking through the eyepiece of the tele-

scope, sees the procession of colors; that is, the spectrum consisting of images of the narrow slit. Each image is formed by light of a particular wavelength. If the light admitted through the narrow slit contains all the wavelengths, the images form a continuous succession. If some wavelengths are missing in the light entering the spectroscope, the spectrum will not be continuous. The place usually occupied by the missing wavelengths will appear black.

The Grating Spectroscope

In a grating spectroscope, the prism is replaced by a grating. This in its simplest form is a piece of glass on which a large number of parallel lines have been drawn. A good grating may have as many as fifty thousand lines to the inch. Light going through a grating will be dispersed into its various colors. The dispersion, however, is not based on refraction as with the prism, but is rather due to interference between light rays that are transmitted in the spaces between the lines on the grating.

There are advantages and disadvantages encountered in using either type of spectroscope. The effective use of either one, therefore, depends upon the work that is to be done.

The grating spectroscope is superior to the prism spectroscope in that it gives a larger spread to the spectrum. The prism spectroscope concentrates the light within a narrow space, producing a brighter spectrum than does the grating spectroscope. It is used exclusively for examining the light coming from faint stars and nebulae.

The spectroscope has indeed helped the astronomer in his observations of heavenly objects. In conjunction with the telescope and camera, it affords him the opportunity to determine the composition of a star, its temperature, speed, direction of motion relative to the earth, distance, and actual brightness. By using the spectroscope, scientists can also analyze samples of matter on the earth and determine their composition and origin.

OTHER ASTRONOMICAL INSTRUMENTS

There are many other instruments which are used by astronomers in studying the vast expanse of outer space. Many of these instruments, however, are too involved in principle for a discussion here. Therefore, we shall devote our attention to some of the more familiar and commonly used ones.

The Stellar Interferometer

The stellar interferometer is used to measure the diameter of stars. It was invented by Albert A. Michelson (1852-1931), the same scientist who successfully measured the velocity of light. An

interferometer used at Mount Wilson can measure the angle made by a star's disk which is about equal to that filled by the head of an ordinary pin when placed in Boston and observed from New York.

The Thermocouple

S. B. Nicholson and Edison Pittit adapted a simple instrument called the "thermocouple" to the measurement of the temperatures of different stars. This instrument is based upon the principle that "if one of two strips of different metals—copper and German silver—held in contact with each other is heated, an electric current is produced." The current can be detected by attaching the thermocouple to a galvanometer and noting the deflection of its needle.

An astronomer's thermocouple is an extremely delicate instrument. The weight of such a thermocouple, including the metal receiver and wires, is about that of one one-thousandth of a drop of water. The thermocouple is operated in a vacuum to prevent the escape of heat by conduction and convection in the air. The effect of the vacuum on a stellar thermocouple is to increase its sensitivity from fifteen to thirty times. The thermocouple utilizes rays both visible and invisible, and the amount of the deflection is proportional to the degree of radiant energy coming from the star(s) being examined.

So sensitive was the thermocouple used by Nicholson and Pittit that if used with the 100 inch reflector telescope, it would detect the heat produced by a candle a hundred miles from the source, providing there were no atmosphere to absorb the candle ray. When the area of about six square yards of star energy gathered in by the telescope is focused on the thermocouple, its temperature is increased about one half-millionth of a degree. The current generated is only about one twenty-billionth of an ampere.

The Bolometer

The bolometer is similar to the thermocouple. It was invented by S. P. Langley and consists of two very fine platinum wires about $1/2500$ of an inch in diameter. These wires are mounted in a constant temperature chamber in such a position that light will strike one wire but not the other. The difference in the electrical resistance of the two wires can be measured with sufficient accuracy to indicate less than $1/1,000,000$ degree rise in temperature.

The Kampometer

C. G. Abbott invented one of the most sensitive heat-measurers known to man. It is called the kampometer. The sensitivity of this instrument exceeds that of the thermocouple or bolometer, from which it differs in principle. It utilizes the principle that two metals expand unequally when they are heated.

Although the instruments discussed have assisted the astronomer enormously in his work, there is an increasing need for better and more precise instruments if his work is going to continue contributing to man's present knowledge of the universe. These instruments are very sensitive and give the astronomer very good results, however, they are not sensitive enough to measure the temperature of the more distant stars. They do serve as checks on methods used to measure the temperatures of the closest stars which may be used to determine the temperatures of more remote stars.

In summary, it can be deduced that the color of a star is a function of its temperature. If a number of stars are arranged according to their colors it will be observed that stars of a given color exhibit characteristic spectra showing varying amounts of such elements as helium, hydrogen or calcium depending upon the temperature. Furthermore, the intensity of radiation of stars varies at different wavelengths.

Questions

1. In astronomy, what are the advantages of photography over the use of naked-eye observation?
2. How does a spectroscope operate?
3. How does a prism spectroscope differ from a grating spectroscope?
4. What is an interferometer? A Thermocouple? Bolometer? Kampometer?

SCIENTIFIC MEASUREMENT

To measure means to compare something (object or body) with an accepted unit of like kind. The physical sciences are intimately involved in four basic concepts: space, time, mass, and energy.

In studying these concepts, we need to measure and make computations. To clarify measurements, basic information is needed in regard to:

1. Length

- a. Area—is the dimension of a surface or plane and is equal to the length of an object times its width. Area is always expressed in a square unit of length.
- b. Volume—is the size of an object in space or quantity of space occupied by an object. It equals the length times the width times the height and is, therefore, expressed as a cubic unit of length.

2. Mass is the quantity of matter inherent in an object. Weight is the pull of a gravitational force upon a mass. Mass is independent of one's location on the earth or in the universe; weight varies according to one's location on a celestial body as well as the force of gravity of that celestial body.

Density refers to the mass of a body per unit volume. It is not synonymous to specific gravity which is the density of a body compared to the density of H_2O (1 gm/cc).

3. Time is considered an interval of duration. The second equals to $\frac{1}{86,400}$ of the time it takes the earth to make one complete turn about its axis. Time can be determined by radioactive decay, the sun, and the stars.

In order for him to perform his tasks competently, it is necessary for man to have units of measurement that are infinitesimally small as well as the enormous units that he uses to measure solar and planetary phenomena. With regards to the former, man relies upon three different systems of measurement to enhance his knowledge about scientific phenomena. The three systems that are in constant use today in the scientific world are:

1. The cgs system—centimeter, gram, second
2. The mks system—meter, kilogram, second
3. The English system—foot, pound, second

Upon careful observation of these three systems of measurement, it will be noted that there exist definite relationships between them. Therefore, we should be able to use each system interchangeably one with another. The work that is being performed by an investigator determines the units, accuracy, and precision of the results.

All of the units of measurement are based upon certain acceptable and agreed upon standards among nations. The original standards are housed in specific locations and they can be observed and examined whenever desired. The exact bases for the generally used units are as follows:

1. The meter is considered to be the measured distance of $1/10,000,000$ from a pole of the earth to the equator along a great circle. More accurately, it is equal to the length of a standard platinum bar at the temperature of melting ice. The standard meter is also taken as a multiple (2.2 million) of the λ of green light emitted by mercury atoms, or 1.6 million times the λ of the orange-red line in the krypton spectrum. The symbol λ is used to represent wavelength.

2. The gram is considered to be $1/10,000,000$ cubic meter of water at its maximum density, or the mass of 1 cc of H_2O at $4^\circ C$.
3. The kilogram is considered to be the mass of an original platinum cylinder that is housed at Severs, France.
4. The liter is considered to be the volume of one kilogram of water at its maximum density, or the volume of 1000 grams of H_2O at $4^\circ C$.
5. The milliliter is considered to be the volume of 1 gram of water. This is equivalent to 1.000027 cc.
6. The yard is considered to be $3600/3937$ of the standard meter.

The accuracy or precision that an investigator uses is dependent upon him and the instruments that he employs. The accuracy of a desired result depends upon the type of work that is being performed. That is to say, the investigator determines the number of decimal places to which he desires his work to be accurate. The precision of a desired result depends upon the instrument that is being used, that is to say, if an investigator wishes to measure the length of a board to the nearest inch and he uses a twelve (12) inch ruler the precision of his results will be to the inch. Should he desire more precision, then he must use a ruler that is divided into $1/4$, $1/2$, etc. depending upon the preciseness of the instrument rather than his own estimations.

The units that have been discussed in the CGS and MKG systems can be divided or expanded as the case may warrant. By using prefixes relating to their meanings, we can arrive at measurements that are comprehensible and at the same time very useful.

The table below illustrates this fact.

UNIT PREFIXES

	Milli	= $1/1000$	= .001
	Centi	= $1/100$	= .01
	Deci	= $1/10$	= .1
UNIT		= $10/10$	= 1.0
	Deka	= $100/10$	= 10.0
	Hecto	= $1000/10$	= 1000.0
	Kilo	= $10,000/10$	= 1,000.0

- B. Schmidt telescope
- C. Stellar energy is converted into an electric current, amplified and recorded graphically
- D. Image is formed by bending the rays of light
- E. Has mirrors which converge light rays; is supplemented by lenses
- F. Used to measure the diameter of stars
- G. Used to measure the temperature of stars
- 3. Spectroscope
- 4. Reflecting telescope
- 5. Interferometer
- 6. Radio telescope
- 7. Hybrid; half reflector and half refractor

- | | |
|--------------|----------|
| II. A. 1000 | 1. mega |
| B. 10^6 | 2. kilo |
| C. 10^{-1} | 3. deci |
| D. 10^2 | 4. deka |
| E. 10^{-3} | 5. micro |
| F. 100 | 6. milli |
| G. 10^3 | 7. centi |
| H. 10^{-6} | 8. hecto |

- | | |
|---|-------------|
| III. A. The mass of a substance per unit volume | 1. Area |
| B. The quantity of matter inherent in a body | 2. Volume |
| C. Expressed as a unit of length squared | 3. Density |
| D. Expressed as a unit of length cubed | 4. Mass |
| E. Grams per cubic centimeter | 5. Pressure |
| F. Pounds per square foot | |

Thought Questions: Record your answer to each of the following questions in its proper place on the answer sheet.

1. What celestial objects were seen by Galileo through his primitive telescope?
2. Describe the type of telescope that was first used by man to observe the heavens.

3. What do these prefixes mean? Kilo, hecto, mega, micro, deci, and milli.

You should realize that for many centuries man had no internationally recognized standards of measurement. The standard unit of length—the meter—is defined by modern man in terms of the wave-length of orange-red light emitted by an isotope of krypton.

Three quantities may be considered fundamental with other quantities expressed or derived in terms of these three. In the English system and metric system, these three fundamental quantities are length, mass, and time.

The quantity 101 meters may be expressed in centimeters by multiplying by 100; that is, by moving the decimal point two places to the right, which gives 10,100.0 centimeters.

TABLE 7-3
English Metric Conversions

To Change	to	Multiply by
Inches	Millimeters	25.4
Inches	Centimeters	2.54
Inches	Meters	0.0254
Feet	Meters	0.3048
Miles	Kilometers	1.609347
Square inches	Square centimeters	6.452
Square feet	Square meters	0.0929
Cubic inches	Cubic centimeters	16.3872
Cubic feet	Cubic meters	0.02832
Pounds	Kilograms	0.45359
Ounces (avoirdupois)	Grams	28.3495
Pounds per square inch	Kilograms per square centimeter	0.0703
Tons	Kilograms	907.185
Millimeters	Inches	0.03937
Centimeters	Inches	0.3937
Meters	Inches	39.37
Meters	Feet	3.281
Kilometers	Miles	0.62137
Square centimeters	Square inches	0.1550
Square meters	Square feet	10.7649
Cubic centimeters	Cubic inches	0.061
Cubic meters	Cubic feet	35.314
Kilograms	Pounds	2.2046
Grams	Ounces (avoirdupois)	0.03527
Kilograms per square centimeter	Pounds per square inch	14.223

Activities

Multiple Choice: For each of the following questions, select the number representing the most complete answer and write it in the proper place on the answer sheet.

1. A standard meter can be defined in terms of:
 1. A multiple of the wavelength of green light emitted by mercury atoms
 2. The distance from the poles to the equator
 3. A multiple of the orange-red line in the spectrum of krypton-86
 4. All of these
 5. None of these
2. Which is the largest? 1. 10 angstroms, 2. 1 light year, 3. 5 A.U., 4. 1×10^6 miles, 5. 4 parsecs.
3. The pull of gravity upon a body is called: 1. mass, 2. inertia, 3. weight, 4. volume.
4. A gram is the mass of 1 cc of water at: 1. 0°C , 2. 32°F , 3. 4°C , 4. 1 or 2.
5. The comparison of the weight of a substance with the weight of an equal volume of water is: 1. area, 2. density, 3. specific gravity, 4. 2 or 3.
6. Which in the preceding question is always expressed as a number with no units?
7. The quantity of space occupied by an object is its: 1. area, 2. volume, 3. density, 4. width.
8. The most accurate geological time is based upon: 1. radioactivity, 2. sedimentation, 3. the amount of salt in the seas, 4. the Dead Sea Scrolls.
9. Which quantity is the smallest? 1. 1 kg, 2. 1×10^6 kg, 3. 550 gm, 4. 100,000 mg.
10. Which does not belong here? 1. second, 2. sidereal year, 3. light year, 4. tropical year.
11. Which quantity is the largest? 1. Your mass on the planet Jupiter, 2. Your mass on the planet earth, 3. Your weight on the moon, 4. Your weight on the planet Mars.
12. To change centimeters to meters: 1. divide by 10, 2. divide by 100, 3. multiply by 100, 4. multiply by 1000, 5. divide by 1000.

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The Earth's Atmosphere: Its Nature and Composition

CONCEPTS:

The atmosphere of a celestial body is the gaseous material surrounding it; it varies with each type of celestial body known to man. Surrounding the earth, this mixture of gases and other components is composed predominantly of nitrogen and oxygen.

The earth's atmosphere serves definite purposes. Not only is it a necessity for plant and animal life, but it also protects us from intense solar radiation and is a prime factor in weather and climate.

The earth's atmosphere is arbitrarily divided into three major layers: the troposphere, the stratosphere, and the ionosphere.

The amount of water vapor found in the air under varied conditions is expressed as the absolute and relative humidity. Moisture is supplied to our atmosphere from many sources and it is found in such forms as rain, clouds, and snow.

The term insolation refers to the energy of the sun's radiation which is modified or reduced by the earth's atmosphere.

The methods by which heat energy is transferred are conduction, convection, and radiation.

A thermometer measures temperature which is the relative hotness or coldness of a substance, but it does not directly indicate the amount of heat energy in a substance.

There is a lowest temperature at which no heat energy exists. At this absolute zero, the molecules of a substance are not in motion and possess no heat energy.

12. The following information is taken from the financial statements of a company for the year ended 31st December 2019:

Revenue 1000
Cost of sales 600
Gross profit 400
Selling expenses 100
Administrative expenses 150
Depreciation 20
Interest on bank loan 10
Income tax 50
Profit before tax 100
Profit after tax 70

Required: Calculate the company's operating profit for the year ended 31st December 2019.

Answer: Operating profit is the profit earned from the company's main business activities, excluding interest and income tax.

Operating profit = Revenue - Cost of sales - Selling expenses - Administrative expenses - Depreciation

Operating profit = 1000 - 600 - 100 - 150 - 20 = 130

Therefore, the company's operating profit for the year ended 31st December 2019 is 130.

13. The following information is taken from the financial statements of a company for the year ended 31st December 2019:

Revenue 1000
Cost of sales 600
Gross profit 400
Selling expenses 100
Administrative expenses 150
Depreciation 20
Interest on bank loan 10
Income tax 50
Profit before tax 100
Profit after tax 70

Required: Calculate the company's net profit for the year ended 31st December 2019.

Answer: Net profit is the profit earned after deducting all expenses, including interest and income tax.

Net profit = Profit after tax = 70

Therefore, the company's net profit for the year ended 31st December 2019 is 70.

14. The following information is taken from the financial statements of a company for the year ended 31st December 2019:

Revenue 1000
Cost of sales 600
Gross profit 400
Selling expenses 100
Administrative expenses 150
Depreciation 20
Interest on bank loan 10
Income tax 50
Profit before tax 100
Profit after tax 70

Required: Calculate the company's contribution margin for the year ended 31st December 2019.

Answer: Contribution margin is the difference between revenue and variable costs, expressed as a percentage of revenue.

Contribution margin = (Revenue - Variable costs) / Revenue

Contribution margin = (1000 - 600) / 1000 = 40%

Therefore, the company's contribution margin for the year ended 31st December 2019 is 40%.

15. The following information is taken from the financial statements of a company for the year ended 31st December 2019:

Revenue 1000
Cost of sales 600
Gross profit 400
Selling expenses 100
Administrative expenses 150
Depreciation 20
Interest on bank loan 10
Income tax 50
Profit before tax 100
Profit after tax 70

Required: Calculate the company's operating leverage for the year ended 31st December 2019.

Answer: Operating leverage is a measure of the degree to which a company's operating income is affected by changes in sales volume.

Operating leverage = (Percentage change in operating income) / (Percentage change in sales volume)

Operating leverage = (70 / 100) / (1000 / 1000) = 0.7

Therefore, the company's operating leverage for the year ended 31st December 2019 is 0.7.

16. The following information is taken from the financial statements of a company for the year ended 31st December 2019:

Revenue 1000
Cost of sales 600
Gross profit 400
Selling expenses 100
Administrative expenses 150
Depreciation 20
Interest on bank loan 10
Income tax 50
Profit before tax 100
Profit after tax 70

Required: Calculate the company's financial leverage for the year ended 31st December 2019.

Answer: Financial leverage is a measure of the degree to which a company's earnings are affected by changes in its capital structure.

Financial leverage = (Interest on bank loan) / (Profit before tax)

Financial leverage = 10 / 100 = 0.1

Therefore, the company's financial leverage for the year ended 31st December 2019 is 0.1.

17. The following information is taken from the financial statements of a company for the year ended 31st December 2019:

Revenue 1000
Cost of sales 600
Gross profit 400
Selling expenses 100
Administrative expenses 150
Depreciation 20
Interest on bank loan 10
Income tax 50
Profit before tax 100
Profit after tax 70

Required: Calculate the company's total leverage for the year ended 31st December 2019.

Answer: Total leverage is a measure of the degree to which a company's earnings are affected by changes in its sales volume and capital structure.

Total leverage = (Percentage change in operating income) / (Percentage change in sales volume) + (Interest on bank loan) / (Profit before tax)

Total leverage = 0.7 + 0.1 = 0.8

Therefore, the company's total leverage for the year ended 31st December 2019 is 0.8.

18. The following information is taken from the financial statements of a company for the year ended 31st December 2019:

Revenue 1000
Cost of sales 600
Gross profit 400
Selling expenses 100
Administrative expenses 150
Depreciation 20
Interest on bank loan 10
Income tax 50
Profit before tax 100
Profit after tax 70

Required: Calculate the company's operating profit margin for the year ended 31st December 2019.

Answer: Operating profit margin is the ratio of operating profit to revenue, expressed as a percentage.

Operating profit margin = (Operating profit / Revenue) x 100

Operating profit margin = (130 / 1000) x 100 = 13%

Therefore, the company's operating profit margin for the year ended 31st December 2019 is 13%.

19. The following information is taken from the financial statements of a company for the year ended 31st December 2019:

Revenue 1000
Cost of sales 600
Gross profit 400
Selling expenses 100
Administrative expenses 150
Depreciation 20
Interest on bank loan 10
Income tax 50
Profit before tax 100
Profit after tax 70

Required: Calculate the company's net profit margin for the year ended 31st December 2019.

Answer: Net profit margin is the ratio of net profit to revenue, expressed as a percentage.

Net profit margin = (Net profit / Revenue) x 100

Net profit margin = (70 / 1000) x 100 = 7%

Therefore, the company's net profit margin for the year ended 31st December 2019 is 7%.

20. The following information is taken from the financial statements of a company for the year ended 31st December 2019:

Revenue 1000
Cost of sales 600
Gross profit 400
Selling expenses 100
Administrative expenses 150
Depreciation 20
Interest on bank loan 10
Income tax 50
Profit before tax 100
Profit after tax 70

Required: Calculate the company's contribution margin ratio for the year ended 31st December 2019.

Answer: Contribution margin ratio is the ratio of contribution margin to revenue, expressed as a percentage.

Contribution margin ratio = (Contribution margin / Revenue) x 100

Contribution margin ratio = (400 / 1000) x 100 = 40%

Therefore, the company's contribution margin ratio for the year ended 31st December 2019 is 40%.

21. The following information is taken from the financial statements of a company for the year ended 31st December 2019:

Revenue 1000
Cost of sales 600
Gross profit 400
Selling expenses 100
Administrative expenses 150
Depreciation 20
Interest on bank loan 10
Income tax 50
Profit before tax 100
Profit after tax 70

Required: Calculate the company's operating leverage ratio for the year ended 31st December 2019.

Answer: Operating leverage ratio is the ratio of the percentage change in operating income to the percentage change in sales volume.

Operating leverage ratio = (Percentage change in operating income) / (Percentage change in sales volume)

Operating leverage ratio = 0.7

Therefore, the company's operating leverage ratio for the year ended 31st December 2019 is 0.7.

22. The following information is taken from the financial statements of a company for the year ended 31st December 2019:

Revenue 1000
Cost of sales 600
Gross profit 400
Selling expenses 100
Administrative expenses 150
Depreciation 20
Interest on bank loan 10
Income tax 50
Profit before tax 100
Profit after tax 70

Required: Calculate the company's financial leverage ratio for the year ended 31st December 2019.

Answer: Financial leverage ratio is the ratio of interest on bank loan to profit before tax.

Financial leverage ratio = (Interest on bank loan) / (Profit before tax)

Financial leverage ratio = 0.1

Therefore, the company's financial leverage ratio for the year ended 31st December 2019 is 0.1.

23. The following information is taken from the financial statements of a company for the year ended 31st December 2019:

Revenue 1000
Cost of sales 600
Gross profit 400
Selling expenses 100
Administrative expenses 150
Depreciation 20
Interest on bank loan 10
Income tax 50
Profit before tax 100
Profit after tax 70

Required: Calculate the company's total leverage ratio for the year ended 31st December 2019.

Answer: Total leverage ratio is the ratio of the percentage change in operating income to the percentage change in sales volume, plus the ratio of interest on bank loan to profit before tax.

Total leverage ratio = (Percentage change in operating income) / (Percentage change in sales volume) + (Interest on bank loan) / (Profit before tax)

Total leverage ratio = 0.8

Therefore, the company's total leverage ratio for the year ended 31st December 2019 is 0.8.

24. The following information is taken from the financial statements of a company for the year ended 31st December 2019:

Revenue 1000
Cost of sales 600
Gross profit 400
Selling expenses 100
Administrative expenses 150
Depreciation 20
Interest on bank loan 10
Income tax 50
Profit before tax 100
Profit after tax 70

Required: Calculate the company's operating profit margin ratio for the year ended 31st December 2019.

Answer: Operating profit margin ratio is the ratio of operating profit to revenue, expressed as a percentage.

Operating profit margin ratio = (Operating profit / Revenue) x 100

INTRODUCTION

Atmospheres vary according to the heavenly bodies which they surround. The stars, Jupiter, Venus, and Mars have different mixtures of gases held to each of them by the different forces of gravity. Some celestial bodies, such as most of the moons in our solar system, have no atmosphere because the gravitational pull is too small to retain the gases and particles that make up an envelope of air.

Since air is free, some of us probably regard it as something of little value. Air, however, is vitally necessary to plant and animal life and serves many other purposes such as protection from the sun's radiations. Some of the many uses for our atmosphere are:

1. Retention of heat energy.
2. Scattering of sunlight.
3. Transmittance of sound waves.
4. Interception of the sun's radiations, thereby protecting us from severe sunlight and high temperatures.
5. Formation of clouds, rain, water, and wind.
6. Providing the necessary energy and chemicals for plant and animal life.

The gases forming the layer of atmosphere surrounding the earth are not combined in a chemical manner. They do not bear a definite proportion to each other and the constituents can be separated by physical means. This is why we say that air is a mixture rather than a compound such as water.

Gases are compressible, which means that the density of the atmosphere varies with the altitude. The density of our atmosphere is greatest at that point closest to the surface of the earth. Density tends to decrease as altitude increases. For this reason, almost one-half of the earth's atmosphere is found within 3 1/2 miles of its surface. Over 99% of our atmosphere lies below a twenty mile altitude. At about 21,000 miles from earth, a region called the exosphere is reached. It is in this region that gas molecules traveling at high speeds may escape into outer space, never to return to earth. The boundary between the earth's atmosphere and interplanetary space approximates 30,000 to 62,000 miles. This is by far a much greater distance than the 600 miles we once thought it to be.

Gases, like other fluids, transmit pressure equally in all directions. That is why we tend to think of air as being very light. However, air has mass which is affected by the earth's gravitational pull; and therefore, it has weight. The weight of our atmosphere is

1. The first part of the document is a list of the names of the persons who have been appointed to the various offices of the Board of Directors of the Corporation.

2. The second part of the document is a list of the names of the persons who have been appointed to the various offices of the Board of Directors of the Corporation.

3. The third part of the document is a list of the names of the persons who have been appointed to the various offices of the Board of Directors of the Corporation.

estimated to be 5,000,000,000,000,000 tons! This is equal to 30,000,000 tons per square mile of the earth's surface. At sea level, the weight of a cross sectional area of one square inch of a column of air as high as the atmosphere is 14.7 pounds. This is the same as saying that the air pressure is 14.7 pounds per square inch. The atmospheric pressure, or the force air exerts over a unit area, is measured in millibars, millimeters, or inches of mercury. The barometer is the instrument used to measure the pressure of the air. An elaboration on pressure is found in a later chapter.

In temperate zones, an average of at least 100,000 tons of water vapor are present over each square mile of the earth's surface. In the tropics, several times this amount of water vapor may be present because warm air can hold more water vapor than cool air.

Questions

1. What is meant by "atmosphere?" Why do atmospheres surrounding celestial bodies vary?
2. Of what use is the earth's atmosphere?
3. How do we know that the atmosphere is a mixture and not a compound?
4. Why is most of the atmosphere found close to the earth's surface?
5. Describe the weight and pressure of our atmosphere.

THE STRUCTURE OF THE ATMOSPHERE

The earth's atmosphere is divided into several levels or layers. The lowest level is called the troposphere; this is the region in which most of our weather occurs and storms are formed. Separating this layer from the stratosphere is the tropopause—a zone that varies in depth over the earth. The stratosphere contains an important layer of ozone which is intimately related to the absorption of the sun's radiation. Above the stratosphere is the ionosphere, a highly charged and very rarefied zone. The atmosphere, especially the upper zone, is studied today by means of satellites launched from earth. These satellites are equipped with instruments which collect and transmit data back to us on the earth's surface.

The Troposphere

That division of the atmosphere which is nearest to the surface of the earth is called the troposphere. Most of our atmosphere, about 75% of the air and water vapor, is found in this region. Its

height averages 11-12 miles at the equator, but only 4-5 miles at the poles.

In this layer, the air is irregular, great air mass movements are formed, and smaller air masses are also formed. (The smaller air masses move because of uneven heating in localized areas). These movements can result in breezes, strong winds, tornadoes, or hurricanes. Jet streams which are swift air currents moving about 80 miles/hour are found within this zone in a region thirty degrees north or south of the equator (the Horse Latitudes). The jet streams are usually found 6-7 miles high in the troposphere and are evidences of the existence of winds in the upper atmosphere.

The troposphere is of prime importance in regulating the temperature of the earth. Within the troposphere, the temperature declines at a constant rate with elevation. This lapse rate, as it is called, equals 19°F per mile increase in altitude. When the lapse rate falls to zero, the temperature remains rather constant. It is above this elevation that the tropopause begins, a division between the troposphere and the stratosphere. This transition zone decreases in height toward the poles.

The Stratosphere

The stratosphere contains no convection currents; therefore, uniform conditions and rather constant temperatures prevail in this layer of our atmosphere. The stratosphere extends to about 50 miles above the earth's surface. Temperatures here are rather constant (about 66°F) and are caused by the action of the sun's ultraviolet light on molecular oxygen, reducing it to ozone. Ozone is the great absorber of solar radiation, and this heated area of the stratosphere is called the "ozone layer." The absorption of ultraviolet rays by ozone may

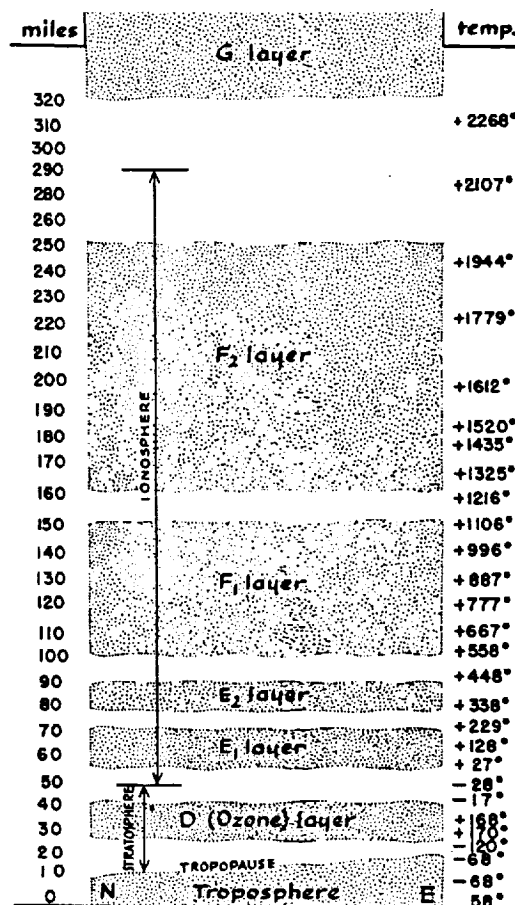


Figure 8-1. The structure of our atmosphere and temperatures at various altitudes. ("The Scientific American")

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be responsible for the relative absence of short ultraviolet radiations in the sun's rays that strike the earth's surface. Because of the uniform conditions that prevail here, airplanes often travel in the lower stratosphere, with passenger compartments sealed and oxygen supplied to both passengers and engines.

The Ionosphere

The very thin layer of air above the stratosphere is called the ionosphere. Its name comes from the fact that charged particles called ions and intense electromagnetic radiations constantly bombard this layer. This radiation includes the cosmic rays, ultraviolet rays, and all charged and uncharged particles coming from the sun. The ionosphere reflects radio waves back to the earth's surface, thus enabling long distance radio reception.

The ionosphere can be subdivided into E₁, E₂, F₁, F₂, and G layers. These five ion layers that may be present in the daytime are active in radio-wave reflection. For example, many amateur short-wave radio communicators use the reflection on the E-layer. Each of the five layers vary in their ability to reflect different radio wavelengths.

Since the ionosphere is over 50 miles above the earth's surface, gaseous molecules such as the oxides of nitrogen can be found. Nevertheless, the air in this zone is too thin to heat bodies like meteors by friction. For this reason we say that meteors visit the ionosphere.

The phenomena called northern lights or aurora borealis of the northern latitudes and its Southern Hemisphere counterpart, the aurora australis, originate in the ionosphere. These as seen by night are forms of light bands or rays across the sky that shift in their pattern and intensity. They are usually greenish in color.

Questions

1. What are the main divisions of our atmosphere? How do the characteristics of these divisions differ?
2. What is the ozone layer? How is ozone formed? Why is ozone so important to us?
3. What are the northern lights?

THE COMPOSITION OF OUR ATMOSPHERE

The composition of the earth's atmosphere is very important to man mainly because plant life produces foods from the carbon dioxide and animals breathe oxygen to abstract energy from these foods. Weather and climate result from the reactions and interactions of

the various components of the atmosphere and this, in turn, directly affects both man and plants.

The earth's atmosphere consists of 99.9% dry air which is intimately composed of a mixture of four gases. This composition at sea level is quite constant except for the water vapor content that varies between wide limits. One of the reasons why the atmosphere has a nearly constant composition, even though it is a mixture, is that it is mobile and expands and contracts with temperature changes. This develops circulation that keeps the atmosphere thoroughly mixed. Table 8-1 shows the composition of dry air near sea level.

TABLE 8-1
The Principal Gases Found in the Earth's Atmosphere
at or Near Sea Level

Name of Gas	Percent by Volume	Percent by Weight
Nitrogen	78.03	75.58
Oxygen	20.99	23.08
Argon	00.93	1.28
Carbon dioxide	00.035	0.053
Other gases	00.0024	0.003

Nitrogen comprises about 78% of dry air. It is a relatively inactive gas which is useful in diluting the rate of oxidation and in the synthesis of food substances. It is extracted from the air by certain bacteria which form compounds of nitrogen vital to plant life.

Oxygen is an active gas essential to man and combustion. It supports all types of oxidation, including decay. Oxygen is the most abundant element in the earth's crust. It combines readily with minerals, metals, fuels, and food to provide the heat and energy in animals. The amount of oxygen in the air remains constant because the amount used balances the amount given back to the atmosphere by plants.

Argon is an inert gas most commonly found in electric light bulbs. By inert we mean that it combines very rarely, if at all, with other elements and substances.

Carbon dioxide is a relatively dense gas with many uses. It is necessary for plant life, the absorption of the sun's radiations, and is an important factor in weathering processes.

About .05-4% of the atmosphere is composed of a gas called water vapor. Although the average amount found in the air is 1%, more of it is located over the tropical areas than the polar areas. When cooled, water vapor can produce rain, snow, hail, sleet, fog,

or dew, and during condensation it releases latent heat energy which supplies energy for storms. It is the only light gas found at a level close to the earth's surface and its amount depends upon the temperature. The capacity of the air to hold water vapor increases with an increase in the temperature. Water vapor also affects the rate of evaporation, humidity, and temperature.

In addition to the gases, the atmosphere also consists of various other components. Dust is found in varying proportions and although dust consists of solid particles larger than molecules, it still is so tiny that it mixes freely with the gases. Dust scatters and diffuses sunlight to produce the colors of the sky. It also absorbs heat energy. Dust provides condensation nuclei for moisture to collect. Bacteria, carbon particles, ammonia, sulfur dioxide, hydrogen sulfide, and carbon monoxide are but a few of the other components of our atmosphere. Some of these are present in small amounts varying with local conditions. Some are even added to the air by man, industrial plants, automobiles, and volcanoes.

Questions

1. Why is the composition of the atmosphere of significance to man?
2. Why would it be impossible for a breathing organism to survive at very high altitudes?
3. What components make up the greatest volume and weight of the earth's atmosphere? Give some uses for each component.
4. Why is carbon dioxide found in larger quantities at low altitudes than at high altitudes?

Forms of Moisture

Fog, rain, clouds, and snow are but a few of the forms of moisture that can be found in our atmosphere. The amount of water vapor present in the air is called the absolute humidity; it can be increased by adding water vapor to the air or decreased by heating or expanding the air. The ratio of the density of water vapor to that of dry air is the specific humidity. Relative humidity is the ratio of the actual vapor pressure to the saturation pressure at a given temperature; or the amount of water vapor in the air compared to the amount the air is capable of containing under the same conditions of temperature and pressure. The air is capable of holding less water vapor or moisture as the temperature decreases.

From Figure 8-2, we can see that at 70°F the air can hold a maximum of 8 grains of moisture per unit volume, whereas at 55°F, the capacity of the air to hold moisture is decreased to 4.8 grains per unit volume. (The higher the temperature, the greater the moisture holding capacity of a unit volume of air).

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LE 15 JANVIER 1954

LE DIRECTEUR GÉNÉRAL DE LA SOCIÉTÉ GÉNÉRALE D'ÉLECTRICITÉ ET DE MÉCANIQUE

LE PRÉSIDENT DU COMITÉ D'ÉTUDES ET DE RECHERCHES

Temperature in °F	Grains of moisture per cubic foot
35	2.4
40	2.8
45	3.4
50	4.1
55	4.8
60	5.7
65	6.8
70	8.0
75	9.4

Figure 8-2. The number of grains of moisture per cubic foot the air can hold at different temperatures.

Relative humidity is expressed as a percentage and absolute humidity is simply the amount of water vapor in pounds, grams, or number of grains per cubic volume (in cubic feet or cubic meters).

To derive the relative humidity, the formula below can be used:

$$\text{Relative Humidity (R. H.)} = \frac{\text{the amount of water vapor in the air (or absolute humidity)} \times 100}{\text{the amount of water vapor the air is capable of holding at a specific air temperature}}$$

For example, if the air temperature is 60°F and there are 4.1 grains of moisture per ft³ in the air, then:

1. The capacity of the air at 60°F is 5.7 grains of moisture per cubic foot.
2. The amount of water vapor in the air at 60°F (A. H.) is 4.1 grains per cubic foot.
3. Substituting in the formula for computing relative humidity, we solve for the R. H. thus:

$$\text{R. H.} = \frac{4.1}{5.7} \times 100 = 72\%$$

This can be interpreted to mean that the air is holding 72% of the water vapor that it is capable of holding at the air temperature of 60°F.

The temperature at which the air is saturated with water vapor or moisture is the dew point temperature. Other ways to express this are: (1) the temperature at which the relative humidity becomes 100%, (2) the temperature at which moisture just begins to

condense out of the air, and (3) the temperature at which dew is formed.

In the preceding example, the absolute humidity was 4.1 grains / cu ft. In this case, the temperature at which the relative humidity would be 100% is 50°F. We can say if the temperature drops to 50°F, the relative humidity would be 100%.

The relative humidity can also be determined experimentally from reading the difference between temperatures on a wet-bulb thermometer and a dry-bulb thermometer as obtained from a sling psychrometer. Table 8-2 shows how relative humidity can be obtained using this method.

TABLE 8-2.

Air Temp. in °F	Depression of Wet-Bulb Thermometer in °F											
	1	2	3	4	6	8	10	12	14	16	18	20
10	78	56	34	13								
15	82	64	46	29								
20	85	70	55	40	12							
25	87	74	62	49	25	1						
40	92	83	75	68	52	37	22	7				
50	93	87	80	74	61	49	38	27	16	5		
60	94	89	83	78	68	58	48	39	30	21	13	5
70	95	90	86	81	72	64	55	48	40	33	25	19
75	96	91	86	82	74	66	58	51	44	37	30	24
80	96	91	87	83	75	68	61	54	47	41	35	29
85	96	92	88	84	76	70	63	56	50	44	38	32
90	96	92	89	85	78	71	65	58	52	47	41	36

Table 8-2. Relative humidity in percent using dry-bulb and wet-bulb thermometer readings. The numbers in the left column are the dry-bulb temperature readings or simply the air temperature readings. After finding the wet-bulb temperature reading, subtract this number from the dry-bulb reading to get the wet-bulb depression. Find the air temperature reading in the left column, read across to the correct wet-bulb depression, and the number that falls under the wet-bulb depression column is the relative humidity. For example, if the air temperature is 50° F and the wet-bulb reading is 46° F, there is a wet-bulb depression of 4° F. In reading across from 50° F to the column under 4° F, the number is found to be 74. This means that the relative humidity of this air sample is 74%.

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Another instrument which is called the hygrometer enables one to read the relative humidity directly. This instrument is found in many homes, schools, and public places.

Fog is considered to be a low cloud consisting of water droplets suspended in the air; these droplets result from humid air found below the dew point.

Clouds are manifestations of water droplets, snowflakes, or ice crystals kept in the air by convection currents or wind. The names of clouds are derived from combining five basic Latin words: cumulus (heap or accumulation), cirrus (lock or curl), stratus (layer or streak), nimbus (rain), and alto (high).

High clouds are those over 20,000 ft. in the sky and generally are named cirrus, cirrostratus, or cirrocumulus. Intermediate clouds range from 6500-20,000 ft. above the earth's surface, and all names of these clouds are prefixed with "alto," such as alto-stratus and altocumulus. Any cloud found 6500 ft. or lower is considered a low cloud. Examples of these would be stratus, nimbo-stratus, or stratocumulus clouds. The cumulus clouds and cumulonimbus clouds are vertically 1600 feet up. The height of the cloud and its degree of darkness can usually indicate the future weather conditions.

Dew is the condensation of water vapor at temperatures above freezing on objects at or near the surface of the earth. Dew collects and does not fall as some people believe.

Rain is the condensation of water vapor at temperatures above freezing at some distance above the surface of the earth. It falls to the earth's surface as a liquid.

Sleet results from the freezing of rain that in turn falls to the earth's surface. Glaze occurs when it rains after a very cold period, with the rain freezing on cold objects or on the ground.

When compacted snow or ice pellets are carried through humid areas, they become coated with moisture and are carried up by the wind under repeated conditions. When this material becomes heavy, it falls to the earth's surface as hail.

Frost, erroneously called frozen dew, results when water vapor freezes directly at or near the surface of the earth. This direct freezing of water vapor is called sublimation. Water vapor, a gas, changes directly to a solid state with no liquid state occurring in the process. The opposite process in which a solid changes directly into a gas, as in the case of moth balls and dry ice, is also termed sublimation.

Sublimation is the process by which snow is formed. This process differs from the formation of frost in that it occurs above the earth's surface and the products fall to the surface.

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Questions

1. Differentiate between: rain and dew, snow and sleet, and frost and dew.
2. How are the names of clouds derived? How can clouds be used to predict weather?
3. How does absolute humidity differ from relative humidity?
4. Define sublimation. Give examples of this process.
5. What is a sling psychrometer? A hygrometer? For what purposes are they used?

HEATING OF THE ATMOSPHERE

The rate of solar radiation is called insolation and is equal to 430 British thermal units of heat falling upon one square foot of the earth's surface per hour. Solar insolation depends upon two main factors: the latitude and the type of absorbing material. Latitude determines the amount of heat energy received, the duration of light energy, and the angle at which light energy strikes the earth. Materials vary in their absorptive power; moist air is better than dry air and ice and snow are good reflectors, whereas land is a poor reflector of heat energy.

Dry air does not absorb much heat energy, but water vapor and moisture do. For this reason, humid areas are warmer at night than dry areas where the radiation from the earth escapes and the temperature drops accordingly. Moisture and water vapor affect the temperature on earth by absorbing the waves radiated from the earth's surface. However, all of the water vapor and moisture in the air averages an exceedingly small amount.

Heat is added to the atmosphere by such factors as conduction, convection, radiation, winds, and ocean air. There is some absorption of direct radiation from the sun, but most of the sun's radiations are too short to be absorbed. Some of the earth's heat energy is obtained from absorption of radiations reflected from the earth's surface. In some cases, absorption of heat radiated from the earth's surface takes place and often the atmosphere is heated by being in actual contact with the heated surface of the earth. The troposphere is heated mostly by convection currents radiated from the warmed surface of the earth.

There is strong absorption of ultraviolet radiation in the upper atmosphere. We have already mentioned ozone as the absorber of long ultraviolet wavelengths and the fact that ozone is in turn changed into oxygen. The earth's surface then absorbs these long ultraviolet wavelengths and reradiates this energy in convective currents from the warmed earth. This process heats the atmos-

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phere, especially the troposphere. We can conclude, therefore, that the atmosphere is heated directly by heat radiated from the earth's surface and indirectly by energy of sunlight.

Electromagnetic radiations from the sun reach the earth as short and long wavelengths. The atmosphere must redistribute the heat and energy from these radiations. Some of this energy is trapped in the lower atmosphere, particularly by such constituents as water vapor and moisture. This effect is similar to that experienced in a greenhouse. In the case of the greenhouse, short wavelengths penetrate the glass and are lengthened. Some are absorbed by the glass and sent back to the greenhouse. The reradiated wavelengths are longer and cannot penetrate back out of the glass. They are trapped inside, and these trapped wavelengths cause the temperature inside the glass to increase. The atmosphere experiences this same process which is called the "greenhouse effect." Without the greenhouse effect, the average temperature of the earth would probably be 50°F colder.

Questions

1. What is meant by insolation?
2. How does the earth's atmosphere modify and reduce the sun's radiations?
3. What is the greenhouse effect?
4. How is the troposphere heated most directly?

Heat vs. Temperature

Most persons are confused by the words "heat" and "temperature." Heat is a form of energy associated with the motions of molecules and atoms; it is measured in calories and British thermal units. A calorie is the amount of heat which will change the temperature of 1 gram of water 1°C. A British thermal unit (Btu) is the amount of heat which will change 1 pound of water 1°F. Temperature is a relative term; boiling water is at a higher temperature than is lukewarm water. On the other hand, a tub of lukewarm water, because of its great mass, may contain more heat energy than a tin cup of boiling water. Temperature is the intensity of heat, the relative hotness or coldness of a body. It determines the flow of heat. Almost everyone has some sense of temperature which means that we can usually estimate which is the warmer of two objects.

Heat is transferred by one of three methods:

1. Conduction: the transfer of energy is directly from one molecule to another molecule as in the case of solids. Metals are in general good conductors and non-metals are poor conductors.

2. Convection: the transfer of energy by streaming molecules or currents. It is particularly characteristic of liquids and gases.
3. Radiation: energy is transferred by waves that cannot be detected by the eye, but which have an effect upon nerve endings of the skin. Solar energy as light energy is received by us on earth due to radiation.

The Measurement of Heat Intensity

In measuring temperature, it is necessary that we use the temperature of some object as a fixed or starting point. There must be some temperature that everyone will agree upon as this starting point. We might use normal body temperature (98.6°F) for such a point, but body temperature varies slightly with different individuals and thus, is not suitable.

It is rather amusing that the most obvious substance, water, was not considered until suggestions of such temperatures as melting butter, a deer's body temperature, the temperature of a cellar in Paris, and the boiling point of alcohol had been discarded. The use of the temperature of melting ice and of water boiling at a barometric height of 76 centimeters (standard pressure) as fixed points is now agreed upon.

Any device which measures temperature is called a "thermometer." The common thermometer used to measure temperature is essentially a sealed glass tube containing a liquid like mercury or colored alcohol. The principle involved in the functioning of a thermometer is that fluids generally expand when heated and contract when cooled. (Solids expand and contract too, but glass in a thermometer does not expand enough to affect the reading materially). The hollow inside of the thermometer, the bore, is very narrow; in some thermometers it is finer than a human hair. Thus, a small change in temperature causes enough expansion or contraction in the liquid to force it a noticeable distance up or down the bore. Since the tube is calibrated, that is, marked in degrees, the temperature can be easily read. Of the many scales that have been invented, only two have survived in general use, the Fahrenheit and Celsius. A third type of thermometer, the Reaumer, has limited use in Europe.

The zero of the common thermometer does not mean "no degree" of heat. It is this idea that many people do not understand. The Fahrenheit zero was adopted because someone arbitrarily decided that the relatively low temperature obtainable with a salt-and-ice mixture was a good starting point for a thermometer scale. The zero of the centigrade scale, which is used throughout the scientific world, is the temperature at which pure water freezes. But it, too, does not mean "no degrees" of heat.

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On the Fahrenheit scale, the two fixed points are 32° and 212°, while on the centigrade scale, they are 0° and 100°. 32°F and 0°C are the temperatures at which ice melts; 212°F and 100°C are temperatures at which pure water boils under standard pressure of 76 cm. Since 180° of equal size separate the fixed points on the Fahrenheit but only 100° separate the same points on the centigrade scale, one Fahrenheit degree is only 5/9 as large as one centigrade degree. When changing a reading from one scale to the corresponding reading on the other scale, we must take this fact into account, as well as the fact that the two scales do not have the same zero; 32°F correspond to 0°C. To change a reading from Fahrenheit to centigrade, we must subtract 32 from the Fahrenheit temperature and then multiply the difference by 5/9; conversely, to change from centigrade to Fahrenheit, multiply by 9/5 and add 32.

$$^{\circ}\text{C} = (\text{F} - 32) \times 5/9; \text{ } ^{\circ}\text{F} = (9/5 \text{ C}) + 32$$

Scientists now know much more about heat than they did when the Fahrenheit and centigrade scales were adopted. These two scales do not indicate absolute temperatures; for the only temperature scale that can indicate absolute readings is the one that starts at the real zero of temperature where there is no degree of heat because there is no motion.

The behavior of gases indicates that there is an absolute minimum temperature, called absolute zero, which is the lowest possible temperature. It has been discovered that the pressure exerted by a gas undergoes systematic reduction as the gas is cooled, provided its volume is held constant. Moreover, regardless of the kind of gas used, the pressure decreases 1/273 of what it is at 0°C for each centigrade degree or 1/460 of its value at 0°F. If the gas could be cooled as a gas to -273°C, or -460°F, it would cease to exert any pressure. If, as scientists believe, heat is responsible for the pressure exerted by gases, the temperature at which the gas would exert no pressure would logically be the temperature at which there would be no heat, or absolute zero degrees.

No known gas follows the above relation throughout a temperature range extending to absolute zero. All real gases condense into liquids before absolute zero is reached, and in liquid form no known substance follows the gas relations.

The temperature scale based on absolute zero is called the Kelvin scale in honor of Lord Kelvin, the British scientist who formulated it. The size of the degree on this scale is the same as that on the centigrade scale. Thus, when converting from the centigrade scale to the Kelvin or Absolute scale, or vice versa, it is only nec-

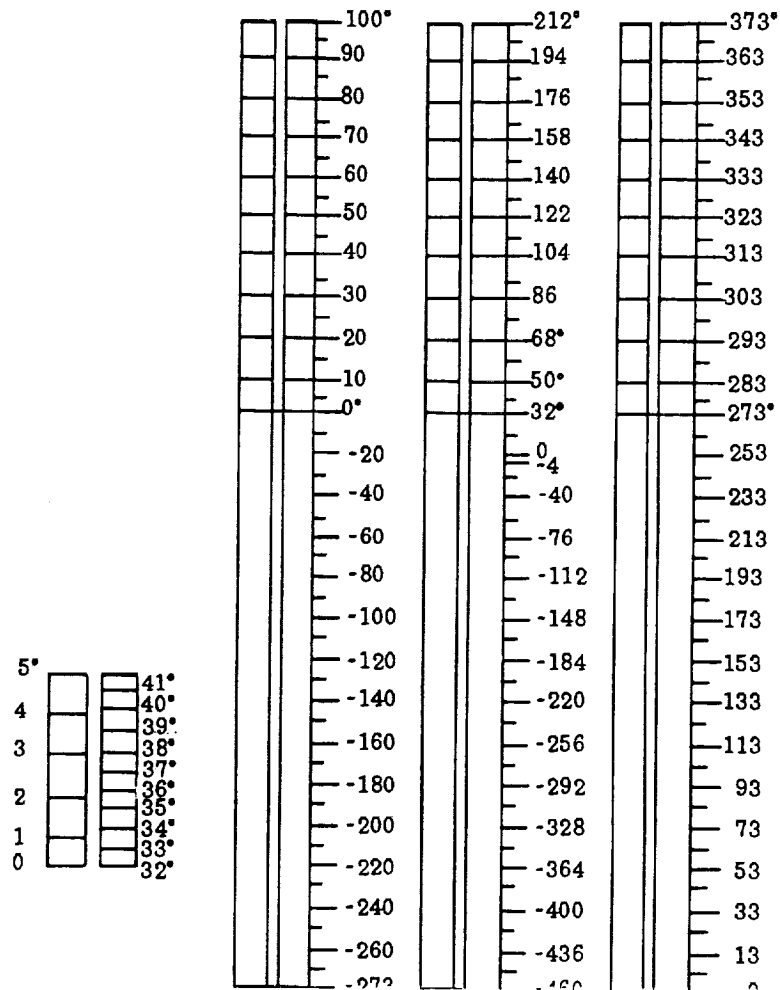
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temperatures which the thermometer is intended to measure. If the fluid freezes solid, it cannot flow; if it boils, it will break the thermometer. The boiling point of mercury (675°F) is high enough to permit its use in the thermometers used at moderately high temperatures. Its freezing point (-40°F) is low enough for its use in average winter temperate zones of climate. Mercury is also used in thermometers because it expands uniformly throughout a wide temperature range.





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Alcohol boils at a much lower temperature reading (172°F) than water and hence cannot be used in thermometers that are to be exposed to high temperatures. Its low freezing point (-202°F), however, makes it useful in polar or arctic regions. Alcohol is cheaper than mercury and more sensitive to temperature variations.

Questions

1. Differentiate between heat and temperature.
2. Compare the boiling and freezing points on the centigrade, Fahrenheit, and Kelvin (Absolute) thermometers.
3. What is meant by the term "absolute zero?"
4. What are the advantages and disadvantages for using mercury, water, or alcohol in a thermometer?

Activities

Multiple Choice: For each of the following questions, select the number representing the most complete answer and write it in the proper place on the answer sheet.

1. Which of the following is chiefly responsible for the absorption of ultraviolet (short) radiation from the sun? 1. water vapor, 2. ozone, 3. moisture, 4. carbon dioxide.
2. Which of the following could be considered a fair weather cloud? 1. nimbus, 2. cumulonimbus, 3. nimbostratus, 4. cirrus.
3. At night, the temperature of the ground lowers because of: 1. reflection, 2. convection, 3. radiation, 4. absorption, 5. insolation.
4. Which gases are most abundant in our atmosphere? 1. nitrogen, argon, carbon dioxide, 2. carbon dioxide, argon, water vapor, 3. argon, oxygen, nitrogen, 4. water, ozone, carbon dioxide.
5. Water absorbs heat _____ and loses heat _____ than land. 1. slower; slower, 2. slower; faster, 3. faster; slower, 4. faster; faster.
6. The process by which heat energy is transmitted through space is: 1. conduction, 2. radiation, 3. convection, 4. all of these.
7. The troposphere is _____ over the North Pole (than as) at the equator. 1. lower, 2. the same height, 3. higher.
8. The troposphere is heated mostly by: 1. direct heating of the air by the rays of sunlight, 2. combustion, 3. convective cur-



- rents that are radiated from the warmed surface of the earth,
4. reflected radiation from the surface of the earth.
9. Insolation depends upon the: 1. latitude, 2. moisture in the air, 3. ozone in the air, 4. carbon dioxide in the air, 5. all of these.
 10. Sublimation is the: 1. process by which snow is formed, 2. process by which frost is formed, 3. direct freezing of water vapor, 4. all of these.
 11. One-half of the earth's atmosphere lies within 3.5 miles of the earth's surface because: 1. of the earth's gravitational pull, 2. dense objects sink, 3. 1 and 2, 4. none of these.
 12. Dew point is the: 1. temperature at which a sample of air is saturated, 2. temperature at which the relative humidity would be 100%, 3. temperature analogous to the absolute humidity, 4. 1 and 2, 5. all of these.
 13. Air containing less than the maximum amount of moisture at a given temperature is: 1. saturated, 2. unsaturated, 3. super-saturated, 4. condensed.
 14. If the temperature of a given mass of air of fixed volume is raised, the absolute humidity: 1. increases, 2. decreases, 3. remains the same, 4. cannot be obtained.
 15. The greater the difference between the wet-bulb thermometer reading and the dry-bulb reading, the: 1. lower the relative humidity, 2. higher the relative humidity, 3. less the wet-bulb depression, 4. 1 and 3, 5. 2 and 3.
 16. When the temperature of the atmosphere is below the dew point: 1. the relative humidity is less than 50%, 2. the absolute humidity cannot be computed, 3. condensation of moisture takes place, 4. no condensation of moisture takes place, 5. the air is unsaturated.
 17. Absolute humidity is: 1. the same as relative humidity, 2. the amount of water vapor in the air at 0°C , 3. the ratio of the density of air to the density of water, 4. all of these, 5. none of these.
 18. With rising temperatures, the ability of the air to contain water vapor: 1. increases, 2. remains constant, 3. decreases, 4. fluctuates.
 - 19.-21. If the air temperature is 65°F and there are 4.8 grains of moisture per cubic foot in the air:
 19. What is the relative humidity? 1. 6%, 2. 14%, 3. 20%, 4. 55%, 5. 71%.

20. What is the absolute humidity in grains per cubic foot?
1. 6.8, 2. 4.8, 3. 5.7, 4. 2, 5. 11.6.
21. What is the dew point? 1. 55°F, 2. 60°F, 3. 65°F, 4. 70°F,
5. 10°F.
- 22.-23. If the air at 75°F has a relative humidity of 61%:
22. What is the absolute humidity in grains per cubic foot?
1. 9.4, 2. 8, 3. 6.8, 4. 5.7, 5. 4.8.
23. What is the dew point? 1. 75°F, 2. 55°F, 3. 65°F, 4. 60°F,
5. 40°F.
- 24.-27. If the relative humidity is 40% and the wet-bulb depression is 14°:
24. What is the dry-bulb thermometer reading? 1. 84°F, 2. 56°F,
3. 0°, 4. 54°F, 5. 70°F.
25. What is the wet-bulb thermometer reading? 1. 84°F, 2. 56°F,
3. 70°F, 4. 54°F, 5. 0°.
26. What is the absolute humidity in grains per cubic foot?
1. 3.2, 2. 32, 3. 1.92, 4. 8, 5. 4.8.
27. Within which range of temperatures is the dew point temperature in Fahrenheit degrees? 1. 35-40, 2. 70-75, 3. 55-60,
4. 40-45.
28. At sea level, atmospheric pressure is approximately:
1. 147 lb/in², 2. 14.7 lb/in², 3. 29.9 lb/in², 4. 30 lb/in²,
5. none of these.
29. Air is a(n): 1. mixture, 2. element, 3. compound, 4. homogeneous solution.
30. The percent of dry air in the earth's atmosphere is approximately: 1. 50%, 2. .003%, 3. 99%, 4. 75%.
31. Without the greenhouse effect, the average temperature of the earth would be: 1. colder than it is now, 2. warmer than it is now, 3. unchanged.
32. Heat can best be described as: 1. a fluid, 2. a gas, 3. convection, 4. energy.
33. When the dry-bulb and wet-bulb thermometers register the same temperature, the: 1. air is saturated, 2. relative humidity is 100%, 3. 1 and 2, 4. none of these.
34. If water vapor condenses above the earth's surface at temperatures below 32°F and falls to the earth's surface, it is called: 1. rain, 2. snow, 3. sleet, 4. frost.
35. Which of the answers in number 34 could occur at temperatures above 32°F?

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Matching: Match the numbered items on the right with the lettered items on the left. Place the numbers of your answers in their proper places on the answer sheet.

- | | | | | |
|-----|----|--|----|-------------------|
| I. | A. | Uppermost zone of the atmosphere | 1. | Specific humidity |
| | B. | Zone containing the ozone layer | 2. | Ionosphere |
| | C. | The temperature at which air becomes saturated | 3. | Dew point |
| | D. | The amount of water vapor present in the air | 4. | Troposphere |
| | E. | Zone where stars shine in the daytime | 5. | Relative humidity |
| | F. | Least dense zone of the atmosphere | 6. | Tropopause |
| | G. | Northern lights emanate from this layer of the atmosphere | 7. | Absolute humidity |
| | H. | The amount of water vapor present in the air compared to the maximum amount the air can hold at that temperature | 8. | Stratosphere |
| | I. | Densest zone of the atmosphere | | |
| | J. | The temperature at which moisture just begins to condense out of the atmosphere | | |
| | K. | The temperature at which the relative humidity is 100% | | |
| | L. | Zone where all of our weather occurs | | |
| | M. | Is expressed as a percentage | | |
| | N. | Important in long distance radio reception | | |
| II. | A. | Supports combustion | 1. | Nitrogen |
| | B. | Very active chemically | 2. | Argon |
| | C. | Commonly found in electric light bulbs | 3. | Oxygen |
| | D. | Relatively dense, poisonous gas | 4. | Carbon dioxide |
| | | | 5. | Water vapor |

- E. Added to the atmosphere by plants
- F. Added to the atmosphere by animals
- G. Only light gas found close to the earth's surface

True-False: In the proper places on your answer sheet, place a "T" for the statements that are true and an "F" for the statements that are false.

1. Normal atmospheric pressure at sea level is equal to 14.7 pounds per square inch.
2. Water vapor is present in the air at all times.
3. Dew falls.
4. A cumulo-nimbus cloud could best be described as low, dark, and massive.
5. Saturn's atmosphere contains ammonia and methane in larger quantities than does the earth's atmosphere.
6. The atmosphere of the sun is rich in oxygen.
7. Jet streams are found in the upper portion of the troposphere near the polar regions.
8. The planet Mercury probably has no atmosphere surrounding it.
9. Temperatures in the stratosphere are rather constant.
10. The instruments used to determine relative humidity are the sling psychrometer, hygrometer, and barometer.
11. Heat and temperature are synonymous terms.
12. Heat energy is transmitted from the sun to the earth by a method called convection.

Thought Questions: Record your answer to each of the following questions in its proper place on the answer sheet.

1. With the aid of Figure 8-3, answer the following:
 - A. How many degrees centigrade are equivalent to one (1) degree Fahrenheit?
 - B. How many degrees Fahrenheit are equivalent to one (1) degree centigrade?
 - C. Formulate an expression for converting temperature on the centigrade scale to degrees Fahrenheit. From degrees Fahrenheit to degrees centigrade.

- D. Describe the condition of a gas if it were possible to reach absolute zero.
 - E. Formulate an expression for converting degrees centigrade and Fahrenheit to absolute.
 - F. What temperature on the absolute scale and Fahrenheit scale are equivalent to 0°C ?
 - G. What is the normal body temperature in centigrade degrees?
2. A piece of iron when heated gets hot very quickly when compared to the heating of the same volume of water. Contrast this difference with the conditions that exist between land and water on the earth. Which one retains heat energy longer?
 3. A student had a "blank" thermometer and desired to calibrate it in terms of degrees centigrade and degrees Fahrenheit. If you were this student, how would you proceed to convert the blank thermometer?
 4. Give several sources of the earth's heat. What is the main source of the earth's heat?
 5. Compare the atmospheric composition of stars, Mars, Jupiter, Saturn, and earth.
 6. What are the names and functions of some of our weather satellites?
 7. Describe the ability of the layers of the ionosphere to reflect different radio wavelengths.
 8. Why is it undesirable for ozone to be found at low altitudes in the troposphere?

FAYETTEVILLE STATE UNIVERSITY

TEACHING INTEGRATED MATHEMATICS AND SCIENCE FOR MIDDLE GRADES

The Earth: Directions, Time, and Seasons

CONCEPTS:

In order to study the features of the earth and travel on its surface, it is necessary to have models and diagrams which describe the positions of places and their direction with respect to the equator and Greenwich Meridian. Some tools used to assist in this endeavor are globes and flat maps.

The earth does not rotate on its axis in an up-right manner; it is tilted at an angle of $23\frac{1}{2}$ degrees to the orbital plane.

The earth is divided into 24 standard time zones, each having a longitudinal width of 15 degrees starting with the Greenwich Meridian.

The different seasons on the earth are due to the different amounts of heat received from the sun at various times of the year. This is caused by the rotation and tilt of the earth on its axis and its revolution about the sun.

There are four points on the earth's path around the sun which are of particular interest and significance. These are the positions of the earth on or near December 21, March 21, June 21, and September 21.

INTRODUCTION

The earth is practically a sphere, and this presents a problem when we attempt to locate places and travel on its surface. To assist us in these endeavors, concrete objects are used that enable accurate plotting of courses and the determination of distances and directions. Since there is no "one" instrument that can be used to accomplish these tasks, scaled models and flat maps are used

supplementary to each other. Obviously, the most desirable of these objects would be models of the earth which are called terrestrial globes. However, these are sometimes expensive, unobtainable, or cumbersome to use. Therefore, in most instances, flat maps will facilitate a study of the features of the earth.

There are two types of flat maps in general use today. These are the Mercator and Equal Area Projection maps. Each of these maps has its advantages and disadvantages. With the Mercator map, we can accurately determine the direction of various places on the earth's surface, but the distances between places are distorted. On the other hand, with the Equal Area Projection map, the distances between places are truly represented, but the directions are distorted. With knowledge of this information and depending upon the work that is to be done, we can utilize the good features of each type of flat map to obtain the type of results desired. (See Figures 4-1.)

Questions

1. What is the general shape of the earth?
2. What instrument(s) or device(s) does man use to assist in determining positions, locations, and features of the earth?
3. Differentiate between an Equal Area Projection and Mercator map. List the advantages and disadvantages of each.
4. What is the best device that can be used to study the earth's features? Why are supplementary devices necessary?

DIRECTIONS ON THE EARTH

The earth rotates on its axis once every 24 hours, with the speed at the poles much faster than it is at the equator. This is due to the earth's diameter at either pole being much smaller than it is at the equator. For a long time it was believed that the earth rotated on its axis in an up-right position; however, it is now accepted that the earth is tilted slightly. This tilt of the earth on its axis has been computed to be $23\frac{1}{2}$ degrees to its orbital plane—an imaginary, horizontal line running through the center of the earth from West to East. (See Figure 4-2). The tilting of the earth on its axis combined with its revolution about the sun is responsible for the seasons of the year.

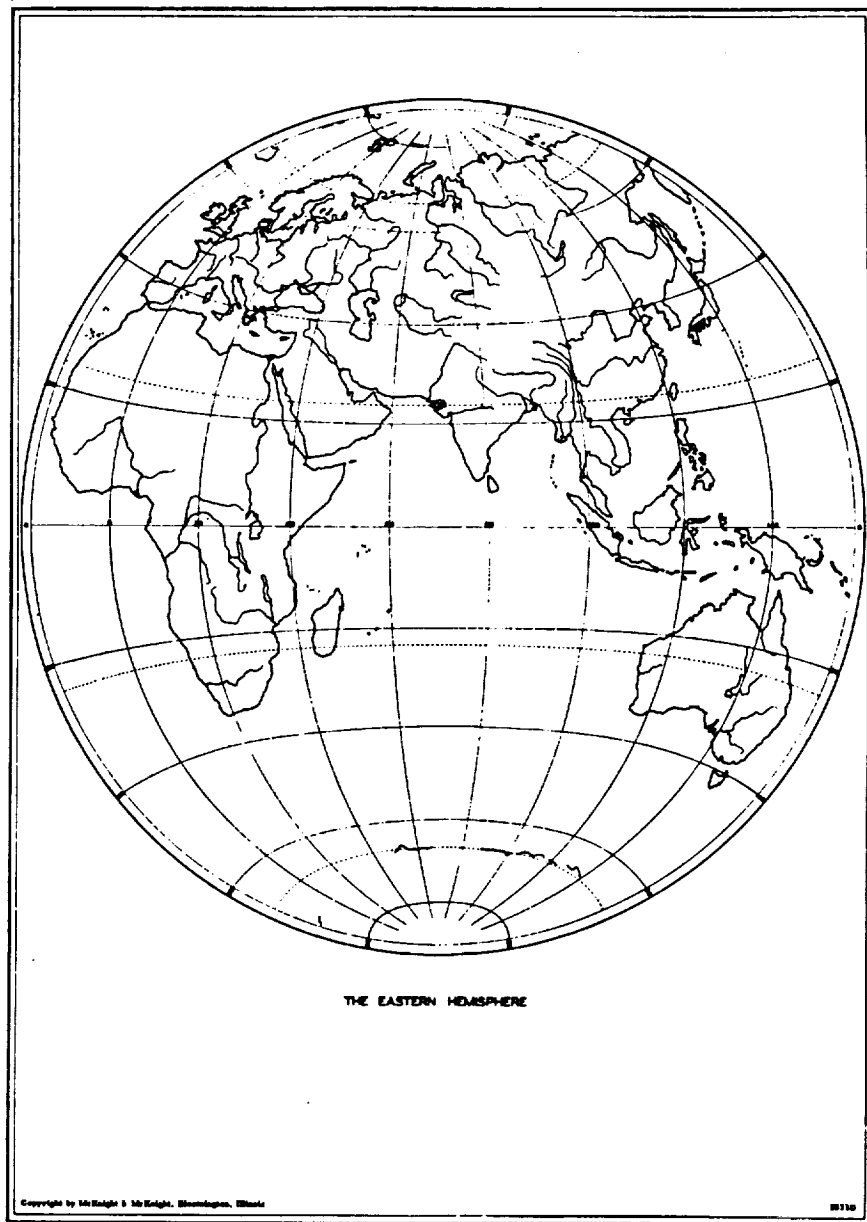


Figure 4-1 (a). Picture of a globe.

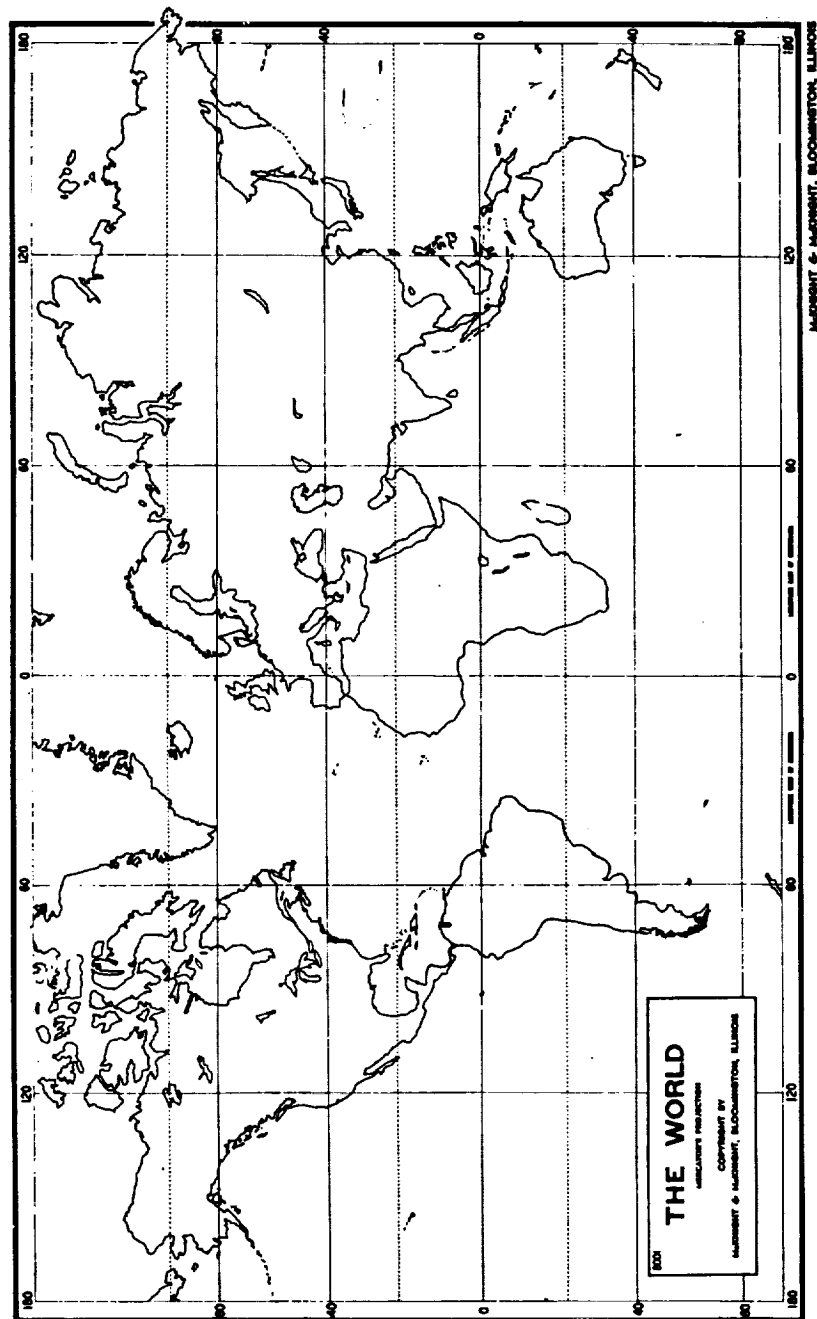


Figure 4-1 (c). Picture of a Mercator map.

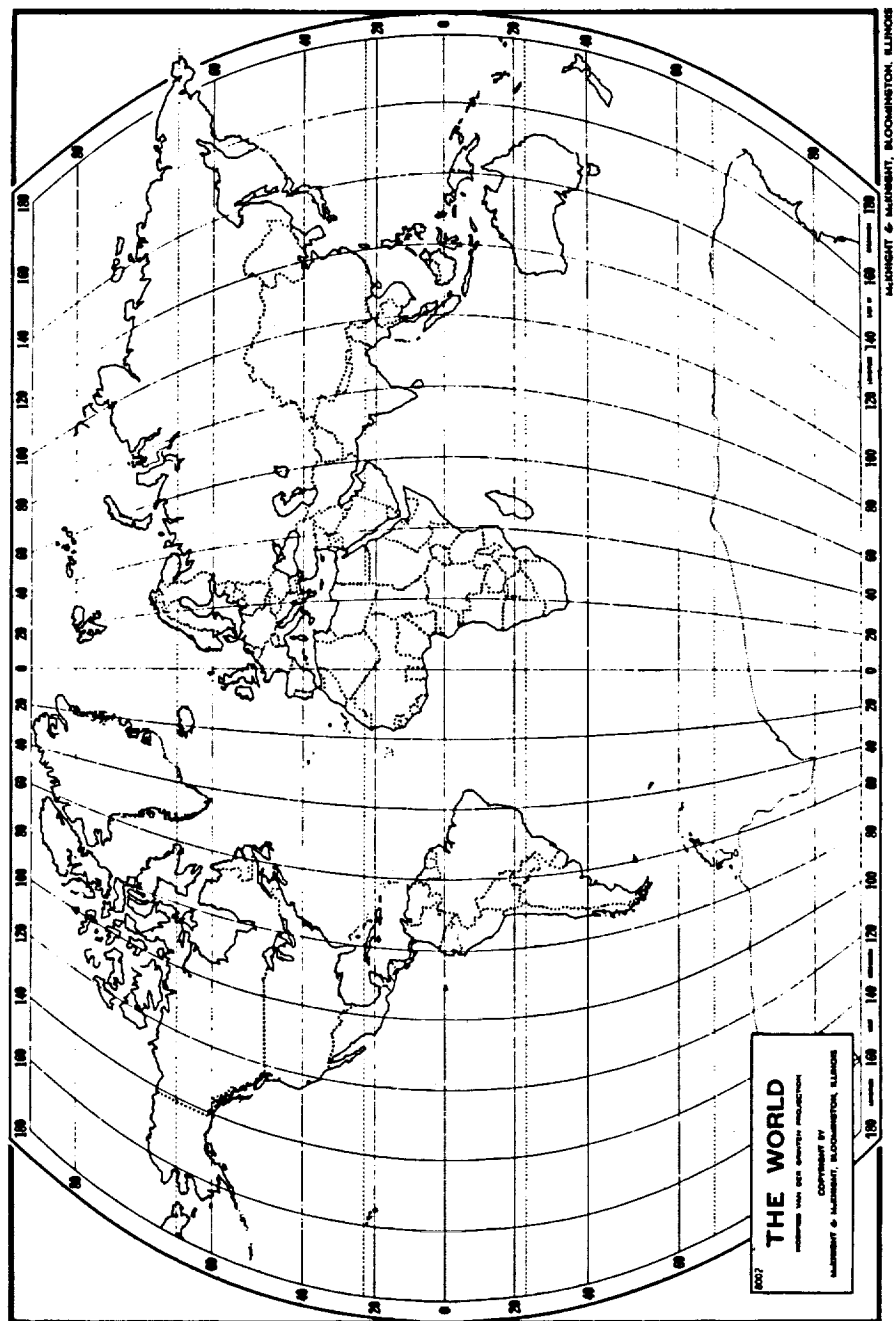


Figure 4-1 (b). Picture of an Equal Area Projection map.

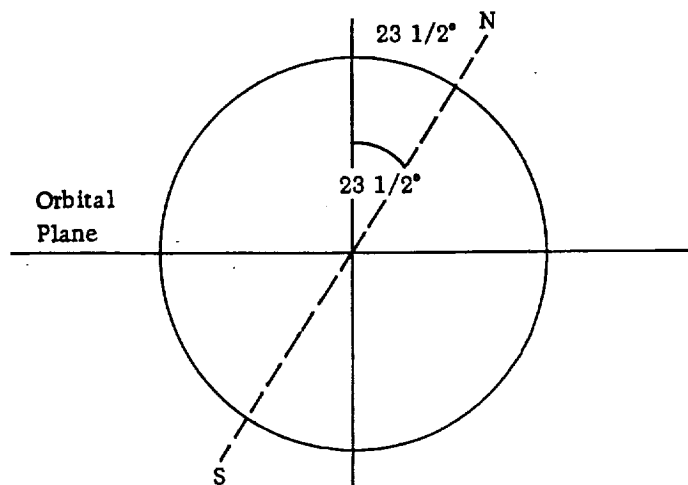


Figure 4-2. Diagram showing tilt and orbital plane of the earth.

There are two types of circles that are used to divide the earth—large and small circles. The large circles define the directions North and South; they are called meridians. The small circles define the directions East and West and are called parallels. One particular parallel that is also a large circle is the equator.

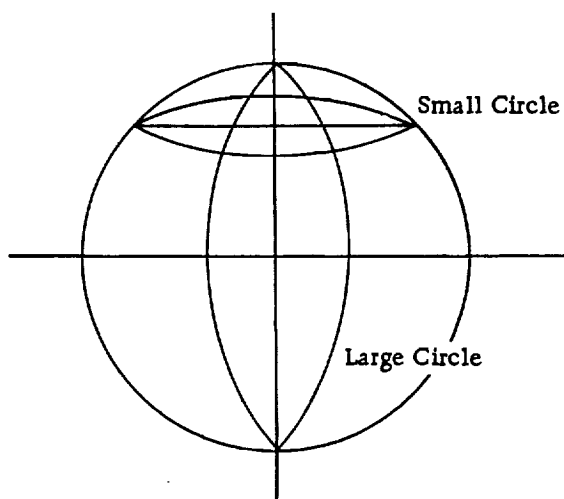


Figure 4-3. Diagram showing small and large circles.

In determining the position of a place on the surface of the earth, it is necessary to know both the latitude and longitude of the

place in question. The angular position of a place with reference to the equator is designated by the term "latitude." This means that a given place must be a definite number of degrees North or South latitude (above or below the equator). The angular position of a place with reference to the Prime Meridian or Greenwich Meridian is designated by the term "longitude." Therefore, a place must be located at a definite number of degrees West or East longitude (to the left or right of the Prime Meridian). Without the latitude and longitude of any place on the earth's surface, it would be impossible for us to accurately locate it.

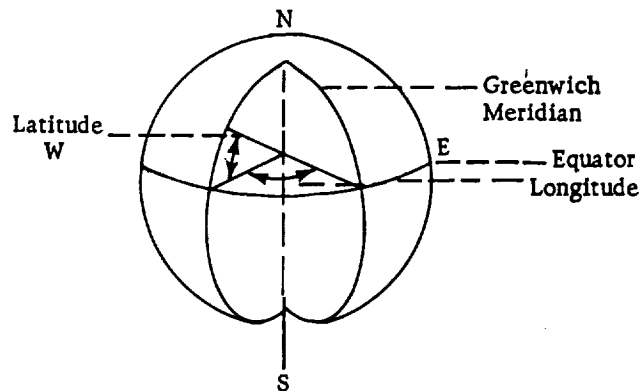


Figure 4-4. Latitude and longitude, where the equator is 0° and the Prime Meridian is 0° .

In traveling on the earth, it is important that we consider the curved feature of this body. The meridians are half-circles composed of 180 degrees that intersect at the North and South Poles. For example, the Greenwich or Prime Meridian and the International Date Line comprise a great meridian circle of 360 degrees. It is important to remember that the distance between meridians is shorter the farther we travel from the equator in a North or South direction. The parallels are equidistant apart. If we travel North from the equator, we can go as far as the North Pole, or 90° . Should we continue traveling along a definite meridian after reaching this point, we must travel South towards the South Pole.

When we travel East or West of the Prime Meridian, our direction never changes. This path of unchanging direction is called a rhumb line, and in traveling along any parallel, we continue in one direction until we arrive at our point of origin. For example, if we desire to travel around the earth in a westward direction, we continue traveling westward until we arrive at the same point from which we started. This does not hold true for those who start in one direction and turn back before completing the circuit around the

1. The first part of the document is a list of the names of the persons who have been appointed to the various positions of the Board of Directors of the company. The names are listed in alphabetical order, and each name is followed by the position to which he or she has been appointed. The names are: Mr. J. H. Smith, President; Mr. J. H. Smith, Vice President; Mr. J. H. Smith, Secretary; Mr. J. H. Smith, Treasurer; Mr. J. H. Smith, Chairman of the Board; Mr. J. H. Smith, Chairman of the Committee on Finance; Mr. J. H. Smith, Chairman of the Committee on Management; Mr. J. H. Smith, Chairman of the Committee on Research and Development; Mr. J. H. Smith, Chairman of the Committee on Public Relations; Mr. J. H. Smith, Chairman of the Committee on Social Responsibility.

earth. This should not be too difficult to understand if we remember that the parallels are small circles, each of which makes one complete revolution around the surface of the earth, or 360 degrees.

Questions

1. How often does the earth rotate on its axis? Describe its position on its axis with reference to a horizontal line drawn through its center.
2. Differentiate between parallels and meridians. Why is the equator considered to be a large circle though it is a parallel?
3. Why must we know both the latitude and longitude of a certain place on the earth's surface if we desire to locate it properly?
4. In what directions do meridians run along the surface of the earth? Parallels?
5. Why is it that we can travel only a certain distance in one direction along a meridian and then our direction must change? What two halves comprise the meridian circle used in differentiating East from West?
6. Why are latitudes and longitudes given in terms of degrees?
7. Why are the parallels equal distances apart, but the meridians are not?

LATITUDE AND DISTANCE ON THE EARTH'S SURFACE

The term "vertical" means perpendicular to the earth's surface at a given point; it is indicated, in practice, by a carpenter's "plumb line." Since the earth is a sphere, however, the perpendicular to the earth's surface at a point is codirectional with the earth's radius at that point. Therefore, the vertical line (plumb line) at a point is the continuation of the earth's radius at that point. So, "up" at one place on the earth's surface is not parallel to "up" at a place a few miles away.

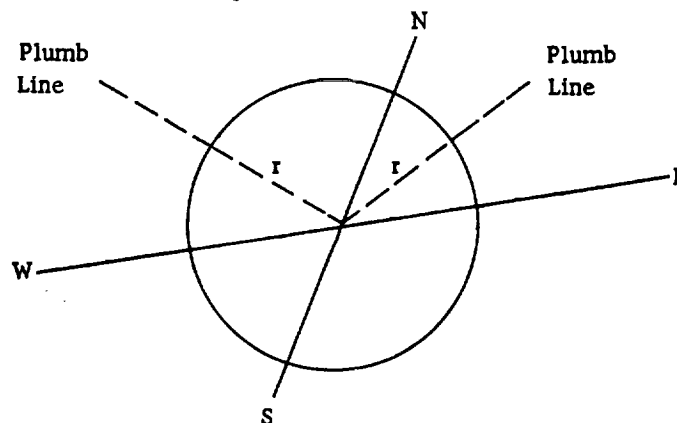


Figure 4-5. A diagram showing plumb lines.

Accurate measurements have shown that if the plumb lines at two different places A and B differ in direction by one degree, then the surface distance measured along the surface of the earth between A and B is about 69 land miles. Since the angle between the two plumb lines is also the angle between the earth's radii to the two points, it follows that the circumference of the earth (a large circle) is approximately:

$$360 \text{ degrees} \times 69 \text{ miles} = 24,840 \text{ miles}$$

and, therefore, the earth's diameter (C/π) is equal to:

$$\frac{24,840}{3.1416} = 7,907 \text{ miles, or approximately } 8,000 \text{ miles.}$$

It should be carefully noted that traveling 69 miles along a small circle will not produce a plumb line shift of one degree because the radius ($1/2$ diameter) of a small circle is not equal to the radius of the earth. It should also be noted that the shortest surface route between two places A and B lies along the large circles passing through the places A and B.

In navigational work, the ordinary land mile is rarely used; instead, the "nautical mile" is found to be more convenient. The nautical mile is $69/60$ of a land mile, therefore, traveling along a large circle through 60 nautical miles produces a shift of one degree in the plumb line.

Questions

1. Describe the concept "up" as it refers to directions on the surface of the earth.
2. Differentiate between land miles and nautical miles. When we use these units, over what areas are we traveling?
3. Which is the larger unit for measuring surface distances: the land or nautical mile?
4. Write the formula for computing the circumference of a circle.

Determination of Latitude

In order for one to determine the latitude of a specific place on the earth's surface, two items of information are needed:

1. The angle between the plumb line at the place in question and the line of sight towards some celestial object (sun, star, moon, or planet) when that object crosses the meridian through the place in question; and



2. The latitude of the place where the celestial object is directly overhead at the time of the observation (the declination of the celestial body).

Since the light rays from the celestial object are parallel, the angle between the plumb line at the place in question and the observer's line of sight to the celestial object, called the "zenith distance," is equal to the angle between the earth's radii at the place in question and at the place where the celestial object is directly overhead. Refer to Figure 4-6.

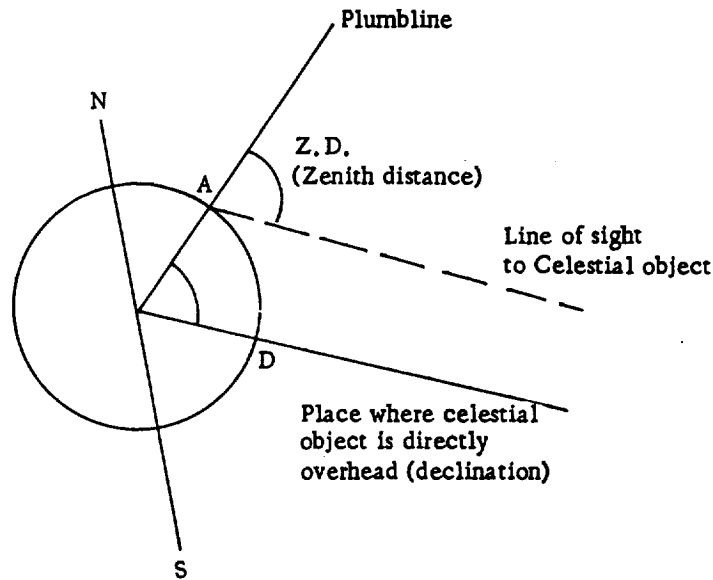


Figure 4-6. Relationship between a plumb line and the line of sight to a celestial object.

If the declination of the celestial object is known, then the latitude can be easily calculated by addition or subtraction as the case may be. Northern latitudes are represented by a positive number; Southern latitudes by a negative number. For example, 30°N would be $+30$ and 30°S would be -30 as substituted or computed in a problem.

The angle between a horizontal line drawn tangent to the earth's surface at a given point and the line of sight to the celestial object is called the "altitude." The angle between the line of sight and the plumb line at the given place is the zenith distance. Therefore, the sum of the altitude and zenith distance is equal to 90 degrees, since the plumb line and horizontal form a right angle.

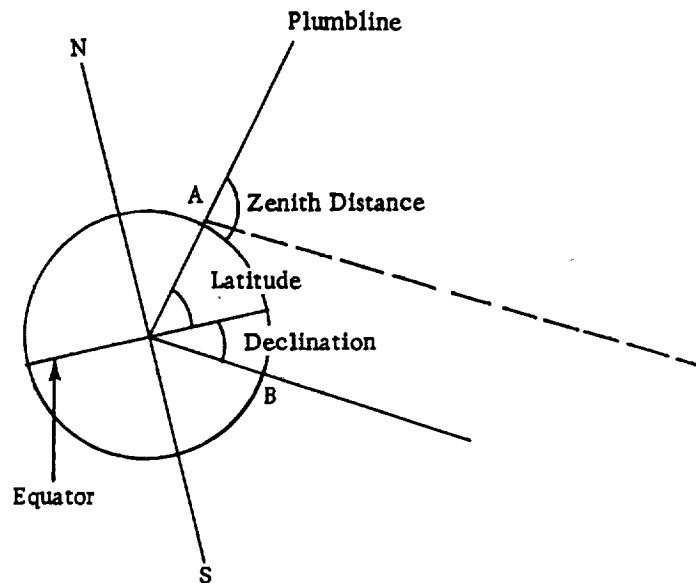


Figure 4-7. Relationship between zenith distance, declination, and latitude.

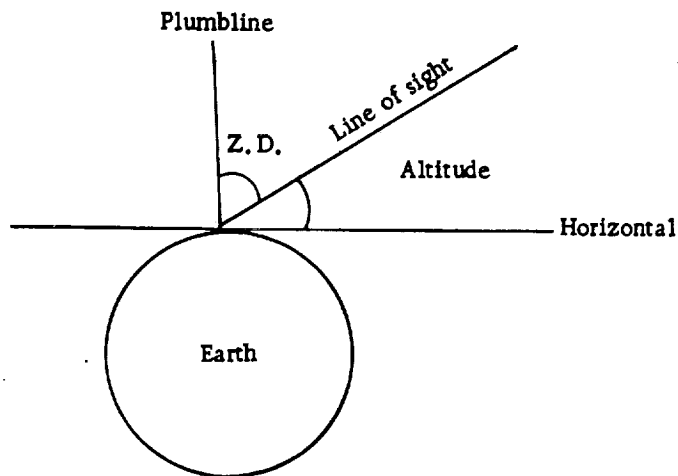


Figure 4-8. The relationship between altitude, zenith distance, horizontal, and plumb line.

The following formulas can assist you to summarize the basic principles thus far discussed:

1. Zenith distance (ZD) + Declination (D) = Latitude (L)
2. Zenith distance (ZD) + Altitude (A) = 90°

therefore,

3. Latitude (L) = Declination (D) + 90° - Altitude (A)

Questions

1. How do we determine latitude on the surface of the earth? State a mathematical relationship for determining this angle.
2. Define the following terms: zenith distance, declination, altitude, plumb line, and latitude.
3. What units are used to represent the terms in question number 2?
4. What is the declination of the North Star?

THE STANDARD TIME ZONES AND LONGITUDE

The earth is divided into 24 standard time zones, each of which has a longitudinal width of 15 degrees. From this arrangement, it can be seen that the earth rotates on its axis 15 degrees every hour or 1 degree every 4 minutes of mean solar time. The instant that the sun is over a given meridian is called "local noon" at that meridian.

Our standard time system is based on the time at Greenwich, England. Since the Greenwich Meridian is considered as the zero (0) degree meridian, and the earth rotates in a counterclockwise manner (West to East) on its axis, for every 15 degrees that the earth rotates, the time decreases (going West) or increases (going East) one hour. This Prime Meridian, also called the Greenwich Meridian, was arbitrarily selected as a reference line and given the longitude of 0°. It has been changed over six times, and in 1588 was moved to Greenwich, England.

In 1884, the International Date Line was setup by the Washington Meridian Conference. This imaginary line position was set between Alaska and Siberia, and it passes through the Pacific Ocean. It is the 180 degree meridian, or the other half of the great circle of which the Greenwich Meridian is one half. To avoid confusion and inconveniences in daily activities and international affairs, the nations of the world agreed to zig-zag this "Date Line" so that it would exclude all land areas along this meridian.

At the International Date Line, the date of our day changes. Countries have agreed that as one travels through the Pacific Ocean Westward and crosses the Date Line, one full day (24 hours) is gained; as one travels Eastward across the Date Line, one full day (24 hours) is lost. Suppose you are traveling to China from the United States and it is 9 A.M. Sunday when your ship reaches the International Date Line, after the ship crosses the Date Line, the time is 9 A.M. Monday. On your return trip, that is, traveling to the United States from China, if it is 10 P.M. Tuesday when the

ship arrives at the Date Line, the time is 10 P.M. Monday when the ship crosses the Date Line. In the latter case, you have traveled in a Westward direction. Refer to Figure 4-9 which shows the relationship among longitude, time, and the International Date Line.

In the United States, we have four Standard Time Zones; that is, Eastern, Central, Mountain, and Pacific. The cities that are located in a particular time zone take their time from the zone in which they are located. Traveling from the Eastern to the Western section of the United States, we gain one hour in time for each time zone we cross. On a return trip, we lose one hour for each time zone we cross. By gaining an hour, we mean that the time is actually one hour behind our present time. It is because of this arrangement and difference in time that people in California can eat a late breakfast and listen to an afternoon radio or television program from New York or Philadelphia.

Questions

1. Describe the time zones as they are represented throughout the world.
2. How many minutes separate each time zone? Hours? Degrees?
3. What is meant by the term "local noon?"
4. Describe the International Date Line. Why does it pass mostly through water?
5. Where does the time of day begin? The date of a day?
6. How do the time zones in the United States differ?

THE SUN, THE EARTH, AND THE SEASONS

Upon examination of the position of the earth on its axis, we find that it is tilted at an angle which approximates $23\frac{1}{2}$ degrees. In considering the factors that are essential for life on our planet, this tilted position of the earth is of tremendous importance, for it determines the amount and intensity of sunlight reaching the earth.

If the earth's axis were perpendicular to the plane of its orbit, the sun's rays would be approximately vertical over the equator at all times, and the equatorial regions would have the same hot, tropical climate year after year. As one passed from the equator towards the poles, he would experience extremely frigid zones around the polar areas. These frigid zones would probably have a much greater area and a much lower summer temperature than they now experience.

This condition would limit further the portions of the earth that support thriving vegetation, with more barren and frozen wastes being found. However, since the earth's axis is inclined from the



perpendicular position, the North Pole is kept pointing approximately toward the North Star (Polaris) and the vertical rays of the sun are received over more areas of the earth.

Questions

1. What effect does the tilt of the earth on its axis have upon climate and weather?
2. If the earth were in a upright position on its axis, how would this affect the weather and climate in the Northern and Southern Hemispheres?

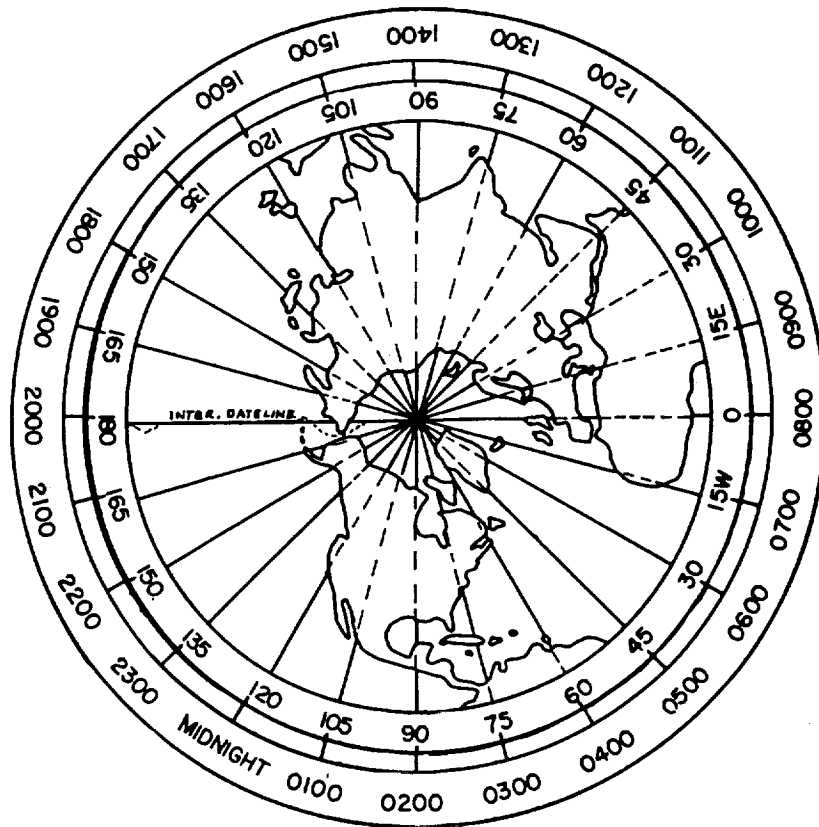


Figure 4-9. Diagram showing longitude, time, and the International Date Line.

The Seasons

There are three factors which are responsible for the Northern and Southern Hemispheres being alternately slanted toward the sun and away from it. These factors are:

1. The earth moves in an elliptical orbit around the sun;
2. The earth is tilted on its axis; and
3. The earth's axis points in the same direction in space, that is, toward the North Star.

The perpendicular rays of the sun cross the equator twice in the course of a year. These dates mark the vernal and autumnal equinoxes which occur about March 21 and September 21, respectively.

On or about March 21, the night in the Northern Hemisphere is the same length as that in the Southern Hemisphere. On this date, at the equator, the sun is directly overhead (90° high) at noon. In this position, the axis of the earth is not tilted away from nor toward the sun, therefore, both hemispheres receive equal amounts of light. On or about September 21, the earth is in a similar position, but on the opposite side of its orbit about the sun. Again, the days and nights are the same length in both hemispheres.

If the earth were not inclined on its axis, the sun would always assume the same position with reference to the earth that it holds on March 21 and September 21. But, during the spring months, as the earth continues its revolution around the sun, the North Pole end of the earth's axis inclines $23\frac{1}{2}$ degrees towards the sun. On or about June 21, the sun at noon appears on the zenith (90° high) of latitude $23\frac{1}{2}^\circ\text{N}$. This imaginary line around the earth is called the Tropic of Cancer. During the season when the sun's rays are near or over this latitude, more intense and perpendicular rays are received at these latitudes. This date, June 21, marks the beginning of the summer solstice and $+23\frac{1}{2}^\circ$ is the greatest northern declination of the sun. It is during this period that the high degree of insolation-heating effect of the sun—stimulates a period of great activity on the part of plants and animals in the Northern Hemisphere.

During the winter months in the Northern Hemisphere, the position of the sun with reference to the earth is reversed, and the Southern Hemisphere is having its summer season. The winter solstice occurs on or about December 21, which marks the date upon which the perpendicular rays of the sun reach their southernmost point. The North Pole is now tilted $23\frac{1}{2}$ degrees away from the sun. At this time the sun's rays shine longer each day in the Southern Hemisphere and the sun is directly overhead at noon in the latitude $23\frac{1}{2}^\circ\text{S}$. This imaginary line around the earth is called the Tropic of Capricorn. The sun appears to remain at this latitude before it starts North again.

It should be noted that the apparent shift of the sun from the Tropic of Cancer to the Tropic of Capricorn and back again is of primary importance in determining changing atmospheric conditions, called weather, and the climate.



The polar zones extend $23\frac{1}{2}$ degrees from the North and South Poles. This area with a torrid zone 47 degrees in width, leaves each intermediate zone approximately 43 degrees wide. It is in these intermediate zones of the earth that the enterprising civilizations of the world flourish.

In studying Figure 4-10, be certain to observe that the earth is tilted at $23\frac{1}{2}$ degrees at each point in the diagram, and remember that the earth rotates also.

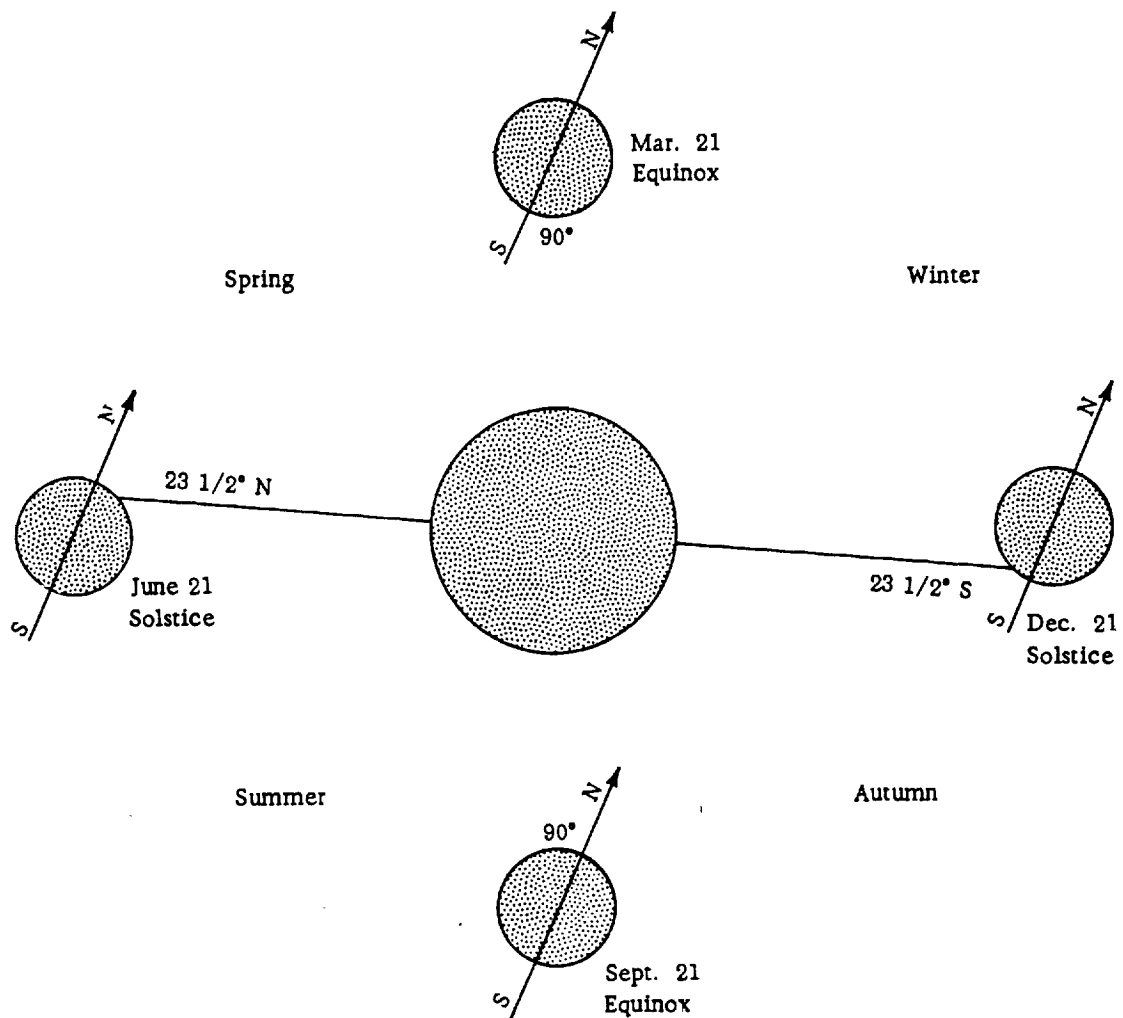


Figure 4-10. Positions of the earth in its path around the sun and the seasons.

Questions

1. Distinguish between the terms equinox and solstice.
2. What is the declination of the sun during the solstices? The equinoxes?



3. What seasons do we experience in the Northern Hemisphere during the equinoxes? During the Solstices?
4. Define the Tropic of Cancer and the Tropic of Capricorn.

Solar Insolation and Hours of Daylight

The amount of heat received by a designated place on the earth depends upon two main factors:

1. The number of hours of sunlight that it receives; and
2. The intensity of the sunlight that it receives.

In the summer months, the days are longer. This means that there are more hours of sunlight to heat the soil, rocks, pavement, and water. Also, in the summer, when the sun rises high in the sky, the strength of the light received from the sun is greater because the beams of light strike more directly or perpendicularly. In winter, when the sun is lower in the sky, our beams of sunlight are slanted and are, therefore, spread over more of the earth's surface. These slanted rays of light heat the areas upon which they fall less intensely. Furthermore, slanting beams travel a greater distance through our atmosphere than those that strike directly. The more air they pass through, the more energy they lose by absorption and, consequently, less energy is left to heat the earth's surface.

Table 4-1 indicates the number of hours of daylight at various places on the earth's surface during the four seasons of the year. You should be able to deduce the number of hours of darkness at each place after studying the information that is included.

TABLE 4-1
The Hours of Daylight at Various Latitudes in the
Northern and Southern Hemispheres

	Hours of Daylight			
	December 21	March 21	June 21	September 21
North Pole	0	12	24	12
Arctic Circle	1	12	23	12
40°N	9	12	15	12
Tropic of Cancer	10 1/2	12	13 1/2	12
Equator	12	12	12	12
Tropic of Capricorn	13 1/2	12	10 1/2	12
40°S	15	12	9	12
Antarctic Circle	23	12	1	12
South Pole	24	12	0	12

Questions

1. Compare the number of sunlight and darkness hours in the Northern Hemisphere during the solstices and equinoxes.



2. Why is the earth receiving more solar radiation in the summer, when farthest from the sun, than in winter, when it is closest to the sun? Why are the winters in the Northern Hemisphere colder than summers?
3. On what date is the sun at its highest point in your sky? The lowest point?
4. If there are 9 hours of daylight at 40°N latitude on December 21, why would it be correct to assume that there would be 15 hours of daylight at 40°S latitude on this date?

Activities

Multiple Choice: For each of the following questions, select the number representing the most complete answer and write it in the proper place on the answer sheet.

1. The position of the earth on its axis is: 1. perpendicular to the plane of its orbit, 2. 23 1/2 degrees to the plane of its orbit, 3. 32 1/2 degrees to the plane of its orbit, 4. parallel to the equator.
2. If the earth were not tilted on its axis, the rays of the sun would always be vertical over the: 1. North Pole, 2. South Pole, 3. equator, 4. International Date Line.
3. If the axis of the earth were perpendicular to the plane of its orbit, which one of the following would be true? 1. There would be more hours of sunlight in the Northern Hemisphere than in the Southern Hemisphere. 2. There would be less available land for vegetation. 3. There would be more hours of sunlight in the Southern Hemisphere than in the Northern Hemisphere. 4. There would be more available land for vegetation.
4. The North Pole of the earth points towards: 1. the sun, 2. the moon, 3. Polaris, 4. Sirius.
5. On September 21, the sun is directly overhead at a certain place "A" which is 600 nautical miles due north of another place "B." The angle between the earth's radii at the two places is: 1. 20°, 2. 5°, 3. 10°, 4. 8.5°.
6. The latitude of place "A" in number 5 is: 1. 23 1/2°N, 2. 0°, 3. 23 1/2°S, 4. none of these.
7. On December 21, the sun is directly overhead at a place "A" which is 1200 land miles due south of another place "B." The angle between the earth's radii at "A" and "B" is: 1. 20°, 2. 1.74°, 3. 2.0°, 4. 17.4°.

8. The latitude of place "A" in number 7 is: 1. $23\frac{1}{2}^{\circ}\text{S}$, 2. 0° , 3. $23\frac{1}{2}^{\circ}\text{N}$, 4. none of these.
9. A certain place "A" is 120 land miles due north of a place "B." On June 21 the sun is directly overhead at place "B" at noon. The angle made by the earth's radii at "A" and "B" is:
1. 17.4° , 2. 2.0° , 3. 1.74° , 4. 20° .
10. The latitude of place "B" in number 9 is: 1. 0° , 2. $23\frac{1}{2}^{\circ}\text{N}$, 3. $32\frac{1}{2}^{\circ}\text{N}$, 4. $23\frac{1}{2}^{\circ}\text{S}$.
11. An airplane traveling eastward arrives at the International Date Line on Tuesday at 10 A.M. The date and time when the airplane crosses the Date Line is: 1. Tuesday at 11 A.M., 2. Wednesday at 11 A.M., 3. Wednesday at 10 A.M., 4. Tuesday at 10 A.M.
12. Which one of the following dates marks the beginning of the winter solstice? 1. September 21, 2. March 21, 3. December 21, 4. June 21.
13. Which one of the above dates in number 12 marks the beginning of the autumnal equinox?
14. The declination of the sun on March 21 is: 1. 0° , 2. $+23\frac{1}{2}^{\circ}$, 3. $+32\frac{1}{2}^{\circ}$, 4. $-23\frac{1}{2}^{\circ}$.
15. On June 21, the sun is directly overhead at noon at:
1. $23\frac{1}{2}^{\circ}\text{S}$, 2. 0° , 3. $23\frac{1}{2}^{\circ}\text{N}$, 4. 90°N .
16. The number of hours of day and night in the Northern Hemisphere on March 21 is: 1. unequal, 2. more day than night, 3. equal, 4. more night than day.
17. On September 21, the sun's declination is: 1. 0° , 2. $+23\frac{1}{2}^{\circ}$, 3. $-23\frac{1}{2}^{\circ}$, 4. $+90^{\circ}$.
18. When the declination of the sun is $-23\frac{1}{2}^{\circ}$ it is: 1. summer, 2. autumn, 3. winter, 4. spring in the Northern Hemisphere.
19. On June 21, which hemisphere receives the greatest amount of sunlight? 1. Southern, 2. Eastern, 3. Western, 4. Northern.
20. On December 21, which hemisphere listed in number 19 receives the greatest amount of sunlight?
21. Which one of the following dates best describes the summer solstice? 1. December 21, 2. June 21, 3. March 21, 4. September 21.
22. The imaginary line around the earth that is of importance on June 21 is known as: 1. the declination of the earth, 2. the Tropic of Capricorn, 3. the inclination of the earth, 4. the Tropic of Cancer.



1

23. The imaginary line around the earth at $23\frac{1}{2}$ degrees South latitude is known as the: 1. Tropic of Cancer, 2. equator, 3. Greenwich Meridian, 4. Tropic of Capricorn, 5. International Date Line.
24. The term which best describes the heating effect of the sun is: 1. inclination, 2. declination, 3. insolation, 4. sublimation.
25. The number of hours that separate the time in New York and California is: 1. 1, 2. 2, 3. 3, 4. 4, 5. 5.
26. If the plumb line at a place "A" makes an angle of 5° with the plumb line at a place "B" then the shortest distance between "A" and "B" in nautical miles is: 1. 345, 2. 600, 3. 300, 4. 30.
27. In number 26, the shortest distance in land miles between the places "A" and "B" is: 1. 300, 2. 30, 3. 345, 4. 600.
28. Two places on the earth's surface are separated by a 30° angle. The number of miles (nautical) that separate the two places is: 1. 2070, 2. 180, 3. 1800, 4. 207.
29. A star is 35 parsecs from the earth. This means that the distance of this star from the earth in light years is: 1. 1.70, 2. 7.9, 3. 114.1, 4. 10.7.
30. The altitude of a celestial body is 45° , therefore, the zenith distance is: 1. 90° , 2. 45° , 3. 60° , 4. 50° .
31. The sun is directly overhead at the Greenwich Meridian. The time of day on the meridian which is 45° east is: 1. 3 A.M., 2. 1 P.M., 3. 3 P.M., 4. 9 A.M.
- 32.-36. The North Star is on the horizon at place X. The sun crosses the meridian of place X seven (7) hours before it crosses the International Date Line.
33. What is the longitude of place X? 1. 75°E 2. 180°W , 3. 75°W , 4. 90°E .
34. The time at the International Date Line is: 1. 12 noon, 2. 5 A.M., 3. 5 P.M., 4. 12 midnight.
35. The time at place X is: (Choose answer from number 34).
36. The latitude of place X is: 1. 45°N , 2. 90°N , 3. 0° , 4. 45°S .
37. The sun is directly over a meridian which is 60° due east of Greenwich. The longitude of a place which is three hours due west of Greenwich is: 1. 30°E , 2. 60°W , 3. 30°W 4. 60°E , 5. none of these.

Matching: Match the numbered items on the right with the lettered items on the left. Place the numbers of your answers in their proper places on the answer sheet.

- | | |
|--|------------------------------------|
| A. A person here can move in only one direction on the earth's surface. | 1. $23\frac{1}{2}^{\circ}\text{N}$ |
| B. The sun is 90° high at noon on the vernal equinox. | 2. 0° |
| C. North Star approximately on the horizon. | 3. $23\frac{1}{2}^{\circ}\text{S}$ |
| D. Sun is 90° high on June 21. | 4. 90°N |
| E. North Star approximately on the zenith. | |
| F. Sun directly overhead twice during the year. | |
| G. Tropic of Cancer. | |
| H. Declination of the sun on December 21. | |
| I. Tropic of Capricorn. | |
| J. Sun is 47° south of the zenith, but 43° high, on December 21. | |
| K. Declination of the sun on June 21. | |
| L. Declination of the sun at noon on the autumnal equinox. | |

True-False: In the proper places on your answer sheet, place a "T" for the statements that are true and an "F" for the statements that are false.

1. A star is a self-luminous body that shines by reflected light.
2. At the equator, there are always 12 hours of daylight and 12 hours of darkness.
3. When the Northern Hemisphere is having winter, the Southern Hemisphere is having summer.
4. In determining the longitude of a place on the earth's surface, we refer to the Greenwich Meridian while the equator is referred to when we consider the latitude.
5. The latitude of a place on the surface of the earth is designated by the directions East and West, while the longitude of a place is designated by the directions North and South.
6. The tilt of the earth on its axis is a major factor in determining the seasons.
7. The Meridian Circle is composed of half that is known as the Greenwich Meridian and another half that is known as the International Date Line.

